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COMPRESSIVE STRENGTH OF STEEL AND IRON.

BY CHARLES A. MARSHALL, M. Am. Soc. C. E.

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The experiments which form the basis of this paper were undertaken with the object of discovering the relation which compressive strength of steel bears to tensile strength. The results appeared to warrant extending the investigation to include wrought-iron, and sufficient tests were made to exhibit the analogy between the two kinds of material.

No attempt has been made to test full sized members of structures, nor any shapes but solid rolled bars as they came from the rolls, except in a few cases where the bars were turned. These were chosen because they are the simplest possible shapes, and it was thought that by eliminating complexity of form and all treatment of the specimens, the properties of the material would be less liable to be obscured. They also possess the advantage of cheapness; are easily obtainable; and permit of a number of tests being made from the same rolled piece, which is not so practicable with larger shapes. Notwithstanding the limitation as to shape, the results are believed to be of value, because they clearly show the relation sought and indicate what appears to be a general law, which is at least clearly demonstrated by the tests so far as solid bars are concerned, namely, that the elastic limit of the material is the chief factor in determining the ultimate resistance of struts of ordinary length made out of

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wrought-iron or steel, excepting the very hardest kinds; and that the two quantities, elastic limit in compression and ultimate compressive strength, are identical within a considerable range of length-ratio of columns.

The writer wishes to state that he was first directed to this law by Mr. James E. Howard, well known as the engineer in charge of the testing machine at Watertown Arsenal. In reply to the query, "What, from his experience, he would say is the compressive strength of wrought-iron?" that gentleman replied that he thought it was about equal to the elastic limit of the material. This view was kept in mind and special attention paid to elastic limit in these tests, and no compression test is included without a corresponding tension test.

The following enumeration of Tables and Diagrams giving results of the tests will afford an idea of the ground covered and facilitate reference:

TABLE No. 1.—Seventy-four flat-ended compression tests of 28 different sizes of bars, .44 to 6.0 square inches section, all from same blow of Bessemer steel. Lengths principally 2, 12, 18, 24 and 30 times shortest diameter.

TABLE No. 2.—Average results of full size tensile tests of the 28 different bars used in tests of Table No. 1.

TABLE No. 3.—Twenty-one flat-ended compression tests of wrought-iron bars, 9 different sizes, made from scrap. Length 2, 12, 18, 24, 30 and 36 times shortest diameter.

TABLE No. 4.—Fourteen tensile tests of the 9 bars of Table No. 3, made on full size pieces cut from each bar.

TABLE No. 5.—Thirty-seven flat-ended compression tests of small steel bars from 18 different casts of steel, ranging from the softest open-hearth steel of 46 000 pounds tensile strength* to high carbon steel of 144 000 pounds tensile strength, also seven tests of two different qualities of iron. Lengths principally 3 times and 12 times the diameter.

TABLE No. 6.—Tensile tests of each bar or set of bars used in tests Table No. 5. Those bars bearing laboratory numbers from 329 to 559 were rolled in sets of four from each heat and cut into test pieces, which were afterwards numbered indiscriminately. Several of each set had been broken, showing very uniform results.

TABLE No. 7.—Compression tests of bars 12 inches long by 1 inch square, cut from each one of 9 rods rolled from the same blow of Cambria 70 000-pounds Bessemer steel; also similar tests from each of 20 bars from a uniform lot of iron purchased from Union Iron Mills of Pittsburg.

TABLE No. 8.—Hinge-ended compression tests of 34 specimens 1-inch square as from rolls, lengths varying from 16 to 60 inches, cut from the same steel rods described under Table No. 7. These will be referred to as "Series W."

TABLE No. 9.—"Series K," in all respects similar to Series W, specimens being cut from the iron rods described under Table No. 7.

* All statements of stresses and strengths in this paper are in pounds per square inch, the actual loads being omitted for the sake of brevity.

TABLE No. 10.—Detail of tensile test of 1-inch square steel from bar W 5, Series W.

TABLE No. 11.—Detail of compression test of 1-inch square steel 4.02 inches long from bar W 5, Series W.

TABLE No. 12.—Detail of tensile test of 1-inch square iron from bar K 11, and summary of tensile test of K 5, Series K.

TABLE No. 13.—Detail of compression test of 1-inch square iron, 3.984 inches long, from bar K 11, Series K.

TABLE No. 14.—Detail of compression test of laboratory No. 2 336a, 1-inch round steel 12 inches long. (Compare Table No. 5.)

The foregoing will be found at end of the paper.

TABLES Nos. 15, 16 AND 17.—Moduli of steel and iron bars in tension and compression, described where introduced.

Plates V, VI, VII, VIII and IX give test diagrams for several of the different classes of material experimented with, the principal results of the tests being also recorded in Tables Nos. 5 and 6. In each case the tensile test is plotted as ordinarily, and also plotted so as to show stress per square inch upon the reduced diameter, abscissas representing percentage of stretch and ordinates the stresses. The compression test of a round specimen 3 diameters long is similarly plotted to exhibit stress upon enlarged diameters, as well as referred to original diameter. The early part of the tensile test, including passage of the elastic limit, is shown also with the horizontal scale magnified ten times, and with it is given the compression test of a specimen usually 12 diameters long.

Plate X is a graphical exhibit of the maximum resistances of bars covered by Table No. 8, Series W.

Plate XI is a graphical exhibit of the maximum resistances of bars covered by Table No. 9, Series K; also graphical exhibit of a series of tests on 3-inch square iron bars made at Watertown Arsenal, a summary of which can be found on page 118 of the Report of Tests at Watertown Arsenal for 1883.

Plate XII shows the form of rocker-bearing used in the hinge-end tests. Its peculiarity is that the axis of the pin is in the plane of end bearing, square ended-specimens being used. Thus, while saving the expense of boring the specimens, all doubt as to effective length of specimen is eliminated, and the pin friction has its proper effect the same as if specimens were bored.

The pins are of hard steel, well fitted and lubricated with a mixture of plumbago, tallow and oil; hence, although their diameter is large as compared with the specimens used, pin friction is very small.

All the tests, except those from the Watertown Report referred to above, were made in the testing laboratory of the Cambria Iron Company, Johnstown, Pa., by whose kind permission I am enabled to lay the results before this Society.

A vertical Emery Testing Machine of 300 000 pounds capacity was used for all except a very few of the smaller tensile specimens, which were tested on a Gill machine of 100 000 pounds capacity.

All specimens whose modulus of elasticity is recorded in the tables had their change of length up to and for a short distance beyond the elastic limit, measured with an electric double micrometer designed by the writer, which reads to the $\frac{1}{10\,000}$ of an inch, though it is not claimed

to be thoroughly reliable closer than .0001 inch. The mode of testing is fairly exhibited in Tables Nos. 10 to 14.

The diagrams were plotted accurately on engraved cross-section paper. They were traced and the plates are photo-lithographs of the tracings.

The short compression specimens were removed and measured with a measuring machine for shortening after each load had been applied one minute or longer, usually a minute, and were measured a number of times during later part of test to determine enlarged area. The diagrams "per square inch actual" were thus not so completely determined as the others, but are however accurate enough to exhibit fairly the comparative behavior under tension and compression. After passing the elastic limit the molecular stress is seen to be greater for a given change of length under compression than under tension, until near the end of tensile test the ultimate tensile molecular stress is seen to be greater than could be obtained with specimens 3 diameters long, except in case of the spring steel, where the two are nearly equal. The closest agreement is in the case of the ductile stay-bolt iron, and the widest divergence in case of the hard iron made from scrap.

Before referring more in detail to the tests, it will be well to define elastic limit as noted in the tables and as used in this paper. Wherever there are no qualifying terms, the limit referred to is what is sometimes called principal elastic limit, sometimes primitive elastic limit.

"Elastic limit by beam" is the same thing when properly taken on soft material.

"Elastic limit by micrometer," in the few cases of hard steel where it is noted, is that point where the change in increment of length due to a certain increment of load is most marked, that being the phenomenon which bears closest resemblance to the principal elastic limit of softer material, the difference being a difference of degree.

In connection with this part of the subject, attention is directed to two phenomena exhibited clearly in all the diagrams of Plates V to IX excepting that of the spring steel. *First.*—When a load equal to the elastic limit of any of these materials is imposed and allowed to remain for some time, it causes permanent change of length, amounting, it is believed, to much more than has been generally understood, and which is apparently a very definite quantity for each case. *Second.*—This change of length having begun under a load equal to elastic limit, will continue under a less load.

The plotted tests in tension were all so made as to develop the amount of this stretch; and it is demonstrated in the cases of the 100 000-pound steel, the 67 000-pound steel, and the hard iron made from scrap, that the total is obtained equally as well, though requiring greater length of time, with a load 1 000 or 500 pounds less than primitive elastic limit as with a load equal to that limit. This becomes

clear from the diagrams, when it is understood that the loads just above the limit were each allowed a minute or more in which to develop stretch.

Time is noted on some of the diagrams sufficiently to give a general idea of the variations in speed of stretching under different loads and at different periods. It is seen that for the same duration of application the less loads cause less change of length. In all the tension and some of the compression diagrams will be seen points where the load was partly taken off and then raised by increments in order to exhibit the second of the phenomena referred to.

The amount of stretch at elastic limit as taken from the tension diagrams:

For the 100 000-pound steel.....	0.3	per cent.
" 80 000 "	1.4	"
" 67 000 "	1.85	"
For hard iron.....	1.3	"
" soft iron.....	2.3	"

It is to be regretted that the same mode of testing was not followed with the shortest compression specimens, but in those which are plotted each load was allowed to act for only about one minute, hence the exact amount of change of length at limit is not clearly shown. It apparently varies from near equality with that under tension to about half as much. The soft iron shows near equality, the hard iron considerably less; the steels near equality, excepting, perhaps, the 80 000-pound steel. The detail test reports, Tables Nos. 10 to 13, furnish the following accurate comparison:

In tension, steel W has	2.11	per cent.
" compression " "	2.05	"
" tension, iron K "	1.38	"
" compression, " "	0.57	"

It is noticeable that the specimens under compression reach their maximum change of length under constant load in less time than those under tension. This appears to be due partially to more rapid action, but is more attributable to difference in length of specimen.

These phenomena may appear trivial to some, but the writer considers that they furnish the key to his subject, and hence attention is further directed to the behavior of the specimen at elastic limit.

Let us follow the course of an experiment for determining elastic limit without the use of measuring instruments. With steel bars having roll scale on, this can usually be done with certainty and dispatch, by setting the speed of straining very small and watching the gradual and continual rise of load till suddenly the load either ceases to rise or else drops materially. Either the first phenomenon or the second is taking place and, as all familiar with testing would recognize, the elastic limit is reached. It is "elastic limit by beam," and this mode of test is prob-

ably more used than any other. Watch should always be kept for the appearance of "scaling," that is the breaks in continuity of the roll scale, which it appears is able to stretch without breaking (in case of steel) up to elastic limit of the steel, but is far too brittle to maintain its integrity under anything like one-half per cent. of stretch. The roll scale on iron seems to be more brittle than is usual on steel, and sometimes begins to drop off before elastic limit is reached. When considerable scaling near ends of specimen and drop of beam first occur simultaneously, the indication of elastic limit is absolute. Certain important conditions, however, are necessary in using this mode of determination.*

For an example of how minute a permanent set is sufficient with the apparatus used to indicate elastic limit by this method see Table No. 11, where a correct indication was had, and the specimen being removed immediately, showed .0035 inch total shortening.

It is of importance to note that this change of length of which we have been speaking, is invariably local and progessive in its action. Thus the scaling can be watched as it proceeds from the ends of a tension or compression specimen towards the center, and the writer has often demonstrated, by means of micrometer measurements, that the central portion of the piece is undergoing no permanent change of length so long as the roll scale remains unbroken between measuring points, and also that as soon as the progressive action has proceeded till the lines of rupture of scale meet at the middle of length, the whole attainable stretch has been had, except an inappreciable fraction.† The load usually fluctuates while this is going on.

If now one tries to imagine a free strut of, say, 20 diameters long, of whatever shape undergoing this change of length, bearing in mind its local progressive character, it requires no great effort of reason to conclude that if the strut at end of the shortening (when it is ready to show increased resistance) is straight, such would be a purely accidental result.

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* Thus if the roll scale is red in color from whatever cause, it will afford a poor indication of elastic limit; such scale or rust possesses very little coherency in itself, and is more strongly attached to the metal. Also a loose rising scale is not permissible. Reheating or tempering spoils the scale for this purpose.

The indication is not accurate with very hard materials; it may be used as a guide and comparative test of steels, but does not furnish a proper quantity to base deductions or calculations upon as regards the cons'ructive value of the material. (See Tables Nos. 5 and 6 for examples of spring steel.) Some irons, such as are granular or brittle, may easily cause erroneous tests by this method.

The specimen must not be crooked, and the grips must be in good condition. This, however, is of less importance when the roll scale is of the best character, since by waiting for appearance of the scaling on body of specimen, and noting the load at that time, the proper determination can be nade.

The speed of straining must be well known by experience, and must never be too great.

The writer uses an instrument to show change of length whenever there is danger that any of the conditions are unsuitable.

† A curious fact is that these lines develop themselves at an angle of 45 degrees in tension and 90 degrees to axis in compression usually.

In a very few of the steel flat-ended tests recorded in the tables, where the length did not exceed 12 diameters, such a condition existed; these specimens usually assumed later an S-curve and gave a little higher maximum load than those which behaved in the usual way, *i.e.*, which bent at some point soon after scaling commenced at the ends, and proceeded to scale on the interior of curve each way toward ends as well as from the ends on the opposite side, producing the well known reversed curve tangent to axis at the ends common to flat and fixed-ended struts, and which is called in the tables "orthodox." The iron specimens in Table No. 7, Series K, afford several instances of a fair degree of straightness being maintained. The other irons tested afford comparatively few, but on the whole iron bars seem more likely to behave in that manner than steel.*

In Tables Nos. 1, 3, 5 and 6, are columns whose heading requires some explanation. That called "Load per square inch at failure," is neither more nor less than elastic limit "by beam," as above described. But in view of the subsequent falling of the load and considerable bending that usually takes place, and of the fact that the same load is the maximum in every case in those tables of a bar longer than 12 diameters, it is described as "failure." The phenomenon certainly impresses one as failure when it is seen. It is not total failure, nor in all cases final failure, but it is failure for the time being to sustain the maximum hitherto imposed load. By continuing the test in those cases where the bar receives an accession of stiffness caused by the most highly distorted portions having completed the change of state at primitive elastic limit, and taken on a new higher limit, sometimes, and more often in case of iron than steel, another maximum load is obtained, sometimes, though not always, exceeding the load at first failure. This is noted as "second maximum." In some cases perhaps a mere fluctuation of elastic limit was mistaken for a true second maximum. The second maximum is likely to be higher in bars which remain straight or take an S-curve during passage of elastic limit, as described in the preceding paragraph.

Turn now to Tables Nos. 1 and 2. These are held to furnish clear and positive proof that crippling strength does not depend upon nor bear any definite ratio to ultimate tensile strength, while the close agreement of the quantities in columns 7, 8, 9 and 10 establish the first part of the general law stated in the second paragraph, or to state it again in slightly

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*It sounds paradoxical, but the explanation probably is because of the greater homogeneity of the steel. Thus the boundary surface between the crippled and uncrippled portions of metal in case of steel will be regular and comparatively smooth, and in case of the fibrous and less homogeneous iron may be irregular and covered with indentations, or points of uncrippled metal projecting into the crippled or flowed metal. It is not difficult to see how this may cause the iron to keep in line better. The layer or extremely short prism of iron or steel undergoing change of state at any instant may be regarded as in unstable equilibrium.

different language, the crippling strength of steel in the form of moderately long struts is approximately equal to the elastic limit of the material. Column 7 was derived from specimens only two diameters long. The tendency is with very short specimens, either in tension or compression, to get too high values for elastic limit. Nevertheless the greatest excess of any qauntity in that column over the corresponding tensile elastic limit is 3 423 pounds and the average excess is 1 370 pounds. The quantities in column 9 for specimens 12 diameters long are believed to be more closely the true compressive elastic limit. The greatest differences between any corresponding quantities, column 9 minus column 8, are + 2 620 and — 1 632, with an average difference of about + 480.

Inspection of column 10 in comparison with column 9 discloses that rarely does the bar exhibit any higher resistance than the elastic limit when 12 diameters long or over. By referring to Column 6 it will be seen that such bars as failed to show crippling strength as great as elastic limit in tension, generally had some defect; or, as noted in one instance, there was failure to stress squarely.

The material for these tests all possessed the same constitution, being from one blow of steel, and is very uniform, as shown by the small variation in ultimate strength, less than 6 000 pounds, notwithstanding the wide range of thickness and sectional area. The tables bring out the fact that elastic limit varies more with size of bar than does any other property of the metal, and there are but two exceptions to the rule that the thicker the bar the lower the elastic limit and ultimate strength.

Table No. 4 shows that the same law applies to iron, though the exceptions are more numerous and the material evidently much less uniform than the steel. Elastic limit varies 11 260 pounds and ultimate strength 9 280 pounds (excluding specimen 2 193, whose low strength is evidently caused by a sliver on the corner of bar). There are some irregularities in each series to be accounted for by irregularities in the heating and rolling. Neither is offered as exhibiting the proper numerical relations of strength, etc., of bars of the same material differing in size.

In Table No. 3 each compression test in column 9 of a piece 12 diameters long is in excess of the corresponding tensile elastic limit, the maximum excess being 1 905 and the average 880 pounds. Out of 13 cases 12 diameters long all but two have a second maximum higher than elastic limit in compression.

Tables Nos. 5 and 6 need little explanation. They serve to extend the application of our law from the softest material called steel up to steel of 100 000 pounds strength, thus covering the whole range of structural steels. Spring steel of 144 000 pounds strength is an exception to the law. The consideration that change of state takes place very gradually and at no one definite load, causing a gradual rounding

of the diagram without any such horizontal portion as shown by the other materials (notwithstanding efforts were made to develop it) shows this to be the exception that proves the rule.

Table No. 7 calls for no further explanation, save that one case of a hinge-ended bar, which bent along axis, is included as flat-ended. The average excess of maximum resistance over compressive elastic limit for flat-ended steel bars is 757 pounds; hinge-ended steel bars, 395 pounds; flat-ended iron bars, 3 171 pounds; and hinge-ended iron bars, 1 807 pounds.

Before discussing the series of bars of varying length whose results are plotted, the modulus of elasticity claims attention, This property of material has been the subject of much loose thought, and widely discordant data have been made public. Many of the widely varying figures, quoted as modulus of elasticity, have been deduced from experiments in bending stress by the common theory of beams, and considering that this theory yields values for ultimate tensile or compressive stress which are in error sometimes to the extent of 50 per cent. or more, we are justified in throwing aside this as no method of determining Young's modulus.

Engineers are to-day, however, in possession of enough data derived from direct tensile experiments to give fairly correct averages for iron and steel. Still in one point many deductions are incorrect, because the total change of length upon first application of loads has been used in the calculations, instead of the change of length recovered upon release of load. The quantity determined by the first of these two modes of calculation will be called modulus of extension or of compression, as the case may be. That by the second mode is the modulus of elasticity (E) in tension or in compression. The two differ more widely in long and large pieces than in light sections, and more in iron than steel, so far as the writer's observations have extended. The cause of the difference is doubtless the presence of internal strains, which are more or less relieved by introduction of permanent sets upon even a single application of stress, and which are greater in large and complicated sections than light ones, and to all appearances greater in iron than steel, comparing the same size of pieces. The difference under tension on small bars is on the average very small.

In Tables Nos. 15 and 16 following, have been collated for comparison all the available determinations elsewhere appearing in this paper. The averages in tension bear out the last statement. The range of load upon which calculations were based varied somewhat, but may be roughly stated as from 5 000 pounds per square inch to three-fourths of the elastic limit. Above that load the modulus of extension will often decrease in value, though many specimens hold to one modulus, very close up to elastic limit. As regards the true modulus E, it is sensibly constant up to the elastic limit, and its variations for different kinds of steel are insignificant.

TABLE No. 15.

Comparison of Moduli for Tension and Compression Steel Bars.
First: Ultimate strength 100 000 or under.

Laboratory No.	Size bar. Inch.	E. Tension in 1 000 lbs.	Modulus of Extension in 1 000 lbs.	Laboratory No.	E. Compression in 1 000 lbs.	Modulus of Compression in 1 000 lbs.	Remarks.
329	1 rd.	30.420	30.190	331	29.740	29.450	
346	$\frac{7}{8}$ sq.	29.850	29.850	348	29.010	28.070	
484	1 rd.	29.500	29.280	476	29.420	28.780	
	1 rd.	.....	.....	479	29.200	28.950	
455	$\frac{3}{4}$ rd.	29.150	29.830	457	29.420	28.580	
464	$\frac{3}{4}$ rd.	29.800	29.670				
497	$\frac{7}{10}$ sq.	29.640	29.420	503	28.670	28.380	
2336	1 rd.	29.630	29.550	2336a	28.830	28.680	
2352	1 rd.	29.960	29.240	2352a	30.490	30.070	
2345	1 rd.	30.420	29.400	2345a	29.790	28.980	
2337	1 rd.	30.370	30.000	2337a	29.810	29.260	
W 5	1 sq.	30.420	29.630				
1667	$\frac{3}{4}$ rd.	.....	.....	1667a	27.880	27.590	
	1 rd.	.....	.....	1669a	27.590	28.780	
	$\frac{3}{4}$ sq.	.....	.....	1595a	.....	27.740	
	1 sq.	.....	.....	1587	28.950	28.080	
	1$\frac{1}{4}$ sq.	.....	.....	1583	28.920	28.780	
1701	3 × $\frac{3}{4}$	.....	29.350	.....	.....	.....	Strip from bar.
1702	3 × $\frac{3}{4}$	.....	29.640	.....	.....	.....	"
1721	3 × 1$\frac{1}{2}$	.....	29.410	.....	.....	.....	"
1722	3 × 1$\frac{1}{2}$	.....	29.860	.....	.....	.....	"
		29.928	29.621	.....	29.123	28.678	Average.

Second: High Carbon Spring Steel. Ultimate strength 144 000.

512	1 sq.	29.960	29.850				
548	1 rd.	29.760	29.480	559	29.330	28.880	
549	1 rd.	29.580	29.390	547	29.200	28.880	
584	1 sq.	29.850	30.530				
576	$\frac{7}{10}$ sq.	29.420	28.880	573	29.220	29.090	
574	$\frac{7}{10}$ sq.	29.200	29.200	579	29.350	29.090	
		29.462	29 535	....	29.275	28.985	Average.

TABLE No. 16.

Comparison of Moduli for Tension and Compression—Iron Bars.

Laboratory No.	Size bar. Inch.	E. Tension in 1 000 lbs.	Modulus of Extension in 1 000 lbs.	Laboratory No.	E. Compression in 1 000 lbs.	Modulus of compression in 1 000 lbs.	Remarks.
2157	$\frac{3}{4}$ rd.	27.500	26.800	2158	26.160	25.840	
2160	$\frac{3}{4}$ rd.	27.410	26.980	2159	26.240	25.920	
2161	1 rd.	26.700	.....	2162	26.440	25.670	
2165	1 rd.	27.540	27.540	2163	26.350	26.020	
2195	$\frac{3}{4}$ sq.	.....	28.990	2196	.....	27.420	
2198	$\frac{3}{4}$ sq.	29.180	27.790	2197	27.790	25.650	
2167	1 sq.	27.900	27 800	2168	27.300	26.490	
2171	1 sq.	28.290	28.2[illegible]	2169	27.990	27.100	
2306	1 rd.	28.570	27.590	2307	28.570	27.250	
2308	1 rd.	28.480	28.290	2309	28.[illegible]70	27.430	
2310	1 rd.	28.480	26.580	2311	28.180	26.500	
2390	$\frac{3}{4}$ rd.	30.190	30.190	2391a	29.910	29.520	
	$\frac{3}{4}$ rd.	.....	.....	2391b	30.120	29.710	
K 11	1 sq.	27.910	23.070				
		28.179	27.992	.....	27.802	26.963	Average.

The following data from a large number of consecutive determinations of modulus of extension of standard ¾-inch round test bars, one from each heat of steel, made in 1885, show the narrow range of averages for the different kinds of steel.

TABLE No. 17.

MODULUS OF EXTENSION OF STEEL BARS.—CAMBRIA IRON COMPANY—TESTING LABORATORY, JOHNSTOWN, PA., 1885.

Number of heats.	Average carbon.	Modulus of extension.—Pounds per square inch.			Kind of steel.
		Lowest value.	Highest value.	Average value.	
33	.09	28 750 000	31 540 000	29 924 000	Bessemer.
89	.34	28 140 000	30 910 000	29 672 000	"
8	.11	29 210 000	30 670 000	30 020 000	Open Hearth.
107	.27	28 310 000	31 180 000	29 996 000	"
25	.72	28 680 000	30 860 000	29 919 000	"

Table No. 17, besides furnishing numerical values very close to the real modulus E, shows that Bessemer steel has lower average modulus of elasticity than good open-hearth steel. It shows also the general law that, other things being equal, the greater the content of carbon in the steel the lower is the modulus of elasticity.

Some further data extracted from the laboratory records, and relating to iron, may also be quoted:

Thirty tests on specimens cut from iron angles and channels of good quality ranged in modulus of extension from 26 740 000 to 30 510 000, with an average of 28 753 000.

Eleven tests of eye-bar iron of good quality ranged in modulus of extension from 27 510 000 to 30 370 000, with an average of 28 797 000.

Six tests of ¾-inch plate-iron of not very good quality, ranged in modulus of extension from 25 880 000 to 27 000 000, with an average of 26 573 000.

The above determinations, including Table No. 17, were all made on Gill knife-edge testing machine with the same micrometer as used in the tests specially made for this investigation.

We come now to Tables Nos. 8 and 9 and Plates Nos. X and XI. Series W and series K are accurately comparable; size and condition of specimens, apparatus and mode of testing being the same in both. They differ from each other only in one being made of 70 000-pound steel and the other of bridge iron, and in the accidental crooks and bends incidental to the bars not having been cold straightened, the deviations due to which at the middle of length are recorded in the column "Condition of specimen." The initial deviation in direction 90 degrees from axis of pins is also written by the side of the plotted test result in the diagrams. On the diagrams are shown the range of elastic limit in compression, and the curve of resistances according to Euler's formula, modulus of compression being adopted from Tables Nos. 15 and 16, in round numbers 28 500 000 for steel and 27 000 000 for the iron bars. It is hoped that the tables furnish a tolerably clear condensed history of each test, enabling one to form an idea of the influence of pin friction and showing how various was the behavior, especially of the longer bars.*

These series, in connection with what has gone before, establish the second part of the law stated in our second paragraph, namely, that elastic limit in compression and ultimate compressive strength are identical within a considerable range of length-ratio of columns. Note that there is but one test in each series which falls below the horizontal belt of range of elastic limit, and that one is of the crookedest, and lies close to Euler's curve in each case.

As regards those results which fall to the right of Euler's curve, they are seen to scatter so widely that, their number being small, they cannot be considered as yielding much more than a suggestion as to how the subject should be studied. The horizontal belt above alluded to is marked by cross-lining, and the belt is extended to the right of the curve by making it to include all specimens whose initial deviation was

*A complete copy of the test records of those bars whose deflections were observed throughout is presented herewith. (See appendix to this paper.) No measurements of shortening were made except at end of test.

.02 inch or under, because bars with so much deviation very generally did as well as perfectly straight ones; bars with greater deviation sometimes do as well, but many drop almost to Euler's curve. The case looks hopeful that with a somewhat extended series of tests varied with reference to crookedness and other purposely introduced defects, such as lack of squareness of end-bearings, eccentricity of end-pressures, etc., quite definite results could be established.

From the closeness and approximate parallelism of lower boundary of the shaded belt to Euler's curve above $\frac{l}{r} = 165$ for the steel and $\frac{l}{r} = 140$ for the iron, it looks as if hereabout are the limits above which Euler's formula should be used pure and simple for hinged ends.

The pins used in these experiments (see Plate XII and description page 55) it is clear exerted very small end-fixing moment upon the bars; no reverse curvature was noticeable upon any above twelve diameters in length $\left(\frac{l}{r} = 42\right)$, so the results probably are on the safe side, supposing the results to be applied to pin-ended columns.

On Plate XI are plotted also the Watertown tests on 3-inch square bars. The range of elastic limit is obtained (probably imperfectly) from a set of three tests recorded in "Report of Tests," Watertown Arsenal, 1882, pages 206–208, stated on page 54 of 1883 Report to be of the same iron. The range of compressive elastic limits is inferred from the tests by the principles set forth in this paper. The main series had 1½-inch pins fitting half holes in ends of bars. Four tests flat-ended, and eight tests with other sizes of pins are also plotted. The enviable agreement of the pairs of tests is attributable in part to the bars having been straightened in a screw press as stated in the Report (see above), it being at the same time evidence of the extreme accuracy of the testing work, while the maintenance of a high strength with long specimens was doubtless aided by the comparatively great pin friction.

Probably the most important fact shown by these three sets of experiments is that the strength of the columns while equal to the elastic limit for a considerable range of length-ratio under that at which Euler's curve crosses the line of elastic limit falls off immediately on crossing the curve. Therefore, for pin-ended columns the length-ratio at which elastic limit ceases to be the measure of the column strength varies with the elastic limit, and is readily determined by plotting the intersection of Euler's curve and a horizontal line representing the elastic limit.

The following theoretical view of the failure of long and moderately long columns of structural steel or iron, accords with the experiments.

All columns being assumed to possess initial eccentricity, a small finite quantity, then:

For frictionless pin-ended, round-ended, or knife-edge-ended columns the formula $\frac{\pi^2 E}{\left(\frac{l}{r}\right)^2}$ is correct, but only applicable so long as E remains constant. If now the modulus of compression changed slowly at and above elastic limit, we might introduce it as a variable into Euler's equation and obtain a curve tangenting the primary curve at the elastic limit, and lying entirely to the left of it. But in this paper it has been shown that at this point E becomes zero, and remains at zero during change of state of the whole, or of that portion of the column whose shortening causes failure. In long columns there is but a small part of the metal that ever passes elastic limit. Making E in the formula $= 0$, gives an absurd result. The formula therefore fails entirely. So long as E remains $= 0$ resistance cannot increase. When the column happens to retain its straightness until there is again a modulus of compression, it would be permissible to reintroduce it and obtain a new formula for specimens which behave that way. But the experiments show that this does not occur with any certainty; very seldom will it occur when $\frac{l}{r}$ is above 42. Below that length-ratio we are not discussing; entirely different conditions of the metal prevail, and the strength of such short pillars has plainly no relation to that of longer ones.

When the column has any degree of fixity of ends (including ordinary pin as well as flat and fixed-ended columns) the effect of such fixity may be treated as diminishing its effective length considered as a frictionless hinge-ended column, according to the usual reasoning, and because elastic reactions of metal are frictionless, therefore the resistances should be represented by $a\,\frac{\pi^2 E}{\left(\frac{l}{r}\right)^2}$, a being greater than unity. But by reason of the statical moment exerted by the ends upon the bearings, and perhaps even in a greater degree depending upon the size and character of those bearings, some load lower than the product of elastic limit by cross-section causes a part or the whole of the cross-section at the ends to reach elastic limit and suffer change of state. This is accompanied by unstable equilibrium (see foot-note, page 59), and the column is at once in the condition of either a frictionless hinge-ended one of a length equal its whole length, or intermediate between its former virtual length and its whole length, according as the fixing moment disappears more or less completely. This new longer length may be such that the load already on is in excess of its appropriate strength and sudden failure ensues.

This explanation seems to fit the series of 3-inch square bars. The Watertown detailed reports show that at from 150 000 to 180 000 pounds load the scale started in front of pins, which means of course that the elastic limit of that portion of metal was passed. At $\frac{l}{r} = 138$, the belt of results reverses its curvature, and the total loads on the two closely agreeing specimens of that length are 183 500 pounds and 180 000 pounds. At $\frac{l}{r} = 159$, the total loads on specimens of that length are

154 150 and 160 500, and from thence to $\frac{l}{r} = 194$, the total loads of 11 specimens out of 12, range but from 147 180 to 160 500, or but 3 000 pounds per square inch on projected intrados of pin-bearings. It seems as if the adjustments of these bars were so perfect that some part of the metal had to pass elastic limit in order to allow the bar to fail at all, and that they otherwise unanimously refused to obey Euler's law up to $\frac{l}{r} = 194$.

Sudden failure may also be caused when the end-fixing moment depends for existence solely upon pin-friction, by the friction of quiescence becoming overmatched by the end-moment. This is believed to have been the case of the writer's experiments with 1-inch squares where the pins were lubricated. The end-bearings of these bars were the full section of the bar, therefore in cases of absolutely perfect adjustment a greater percentage of the full elastic limit is obtainable than if the bearings had been smaller, because the ends will not pass elastic limit with so small a load. Compare two tests with deviation .00 at $\frac{l}{r} = 132$ and 138, diagram for 1-inch square iron with upper limit of belt of 3-inch square tests.

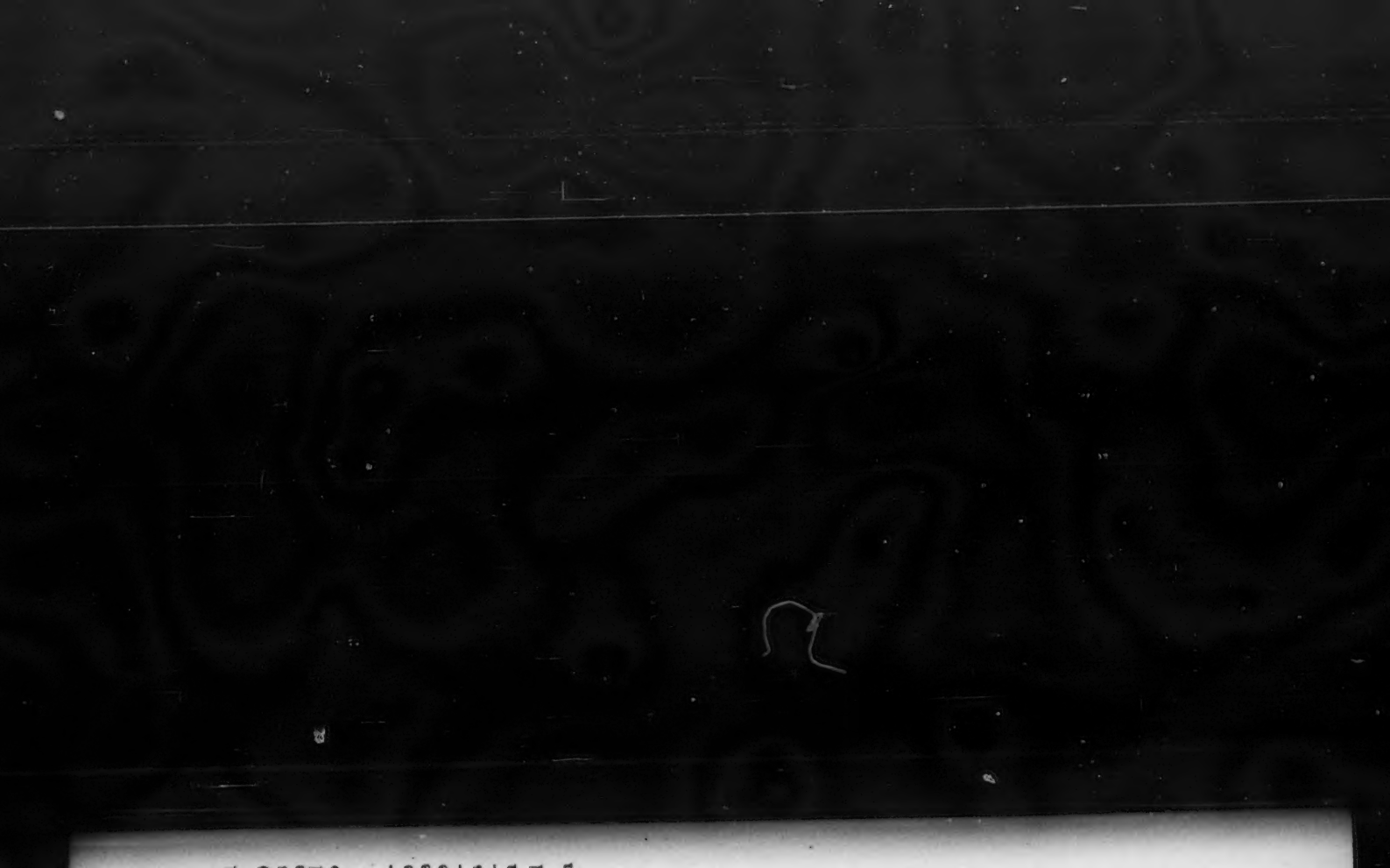

TABLE No. 1.

Compression Tests of Steel Bars. All from same Blow of Bessemer Steel, "as from Rolls."—Testing Laboratory of Cambria Iron Company, May, 1886. C. A. Marshall, Engineer of Tests.

1 Laboratory number.	2 Dimensions of cross-section. Inches.	3 Length. Inches.	4 Length. Diameters.	5 $\frac{l}{r}$	6 Condition of piece before test (all being full size as from rolls).	7 Elastic limit compression. Pounds per square inch.	8 Elastic limit. Tension. See Table No. 2.	9 Load per square inch at failure.	10 Second maximum. Pounds per square inch.	11 Load per square inch at removal.	12 Modulus of elasticity. Pounds per square inch.	13 Permanent shortening. Per cent.	14 Permanent deflection. Inches.	15 Permanent shortening with 100 000 pounds per square inch. Per cent.	16 Remarks.
1667a	¾ round	1.5	2	....		47 300	46 090	.....	.....	.....	.....	....	....	14.8	
1667	¾ "	9.37	12.5	50		.....		44 980	45 580	.....	27 880 000	....	.09	....	Gave way 3 inches from end.
1669a	1 "	2	2	....		46 170		.....	.....	.....	.....	....	....	14.8	Under 200 000 lbs. per sq. in. original, shortening = 47.0 per cent. This equals 99 550 lbs. per sq. in. actual enlarged area at center.
1669b	1 "	2	2	....		45 870	44 202	.....	.....	.....	.....	....	....	14.9	
1669	1 "	12	12	48	Gentle curve, .03 inch ordinate central	.....		44 000	44 000	33 410	27 590 000	1.25	.38	....	Flexed orthodox.
1551a	1¼ "	2.5	2	....		42 970	40 747	.....	.....	.....	.....	...	....	15.2	
1551b	1¼ "	2 5	2	....		43 950		.....	.....	.....	.....	....	....	15.2	
1551	1¼ "	15	12	48	Bent, .035 inch ordinate 5 inches from end	.....		40 850	None.	22 060	.....	2.67	1.06	...	Flexed orthodox, ends scaled first.
1544a	1½ "	3	2	....		41 720	40 275	.....	.....	.....	.....	....	....	15.4	
1544b	1½ "	3	2	....		40 860		.....	.....	.....	.....	....	....	15.3	
1544	1½ "	18	12	48	Straight	.....		41 880	None.	28 870	.....	1.78	.78		
1543a	1¾ "	3.5	2	....		42 870	40 017	... ..	.....	.....	.....	....	....	15.3	
1543b	1¾ "	3.5	2	....		41 280		.....	.....	.....	.....	....	....	15.3	
1543	1¾ "	21	12	48		.....		39 950	39 910	31 690	.....	1.52	.71		
1539a	2 "	4	2	....		40 620	38 207								
1539b	2 "	4	2	....	One end shows bruise of shear blade	37 040									
1539	2 "	24	12	48		.....		40 850	None.	31 990	.....	1.29	.74	....	Flexed orthodox.
1535a	2¼ "	4½	2	....		38 300	.....								
1535b	2¼ "	4½	2	....		37 950									
1535	2¼ "	27	12	48		.....		36 790	37 130	33 050	.....	1.59	.80		
1534	2¼ "	40.5	18	72		.....		36 580	None.	25 500	.....	.69			
1530a	2½ "	5	2	....		35 740	36 100								
1530b	2½ "	5	2	....		37 940									
1530	2½ "	30	12	48		.....		35 650	None.	32 650	.....	1.10	.75	....	Gave way, ends and middle together.
1531	2½ "	44	17.6	70	Shows bruise and bend caused by shear blade at one end	.....		34 450	None.	26 270	.....	.48	.89		
1595a	¾ square	1½	2	....		44 290	44 273	.....	.....	.....	.....	....	....	14.6	
1595b	¾ "	1½	2	....		43 400		.....	.....	.....	.....	....	....	14.4	
1595	¾ "	9.37	12.5	45		.....		44 960	44 210	37 490	27 740 000	1.92	.28	....	Flexed orthodox.
1591a	⅞ "	1.6	2	....		49 750	47 815	.....	.....	.....	.....	....	....	13.9	
1591b	⅞ "	1.6	2	....		48 360		.....	.....	.....	.....	....	....	14.0	
1587a	1 "	2	2	....		44 025		.....	.....	.....	.....	....	....	14.9	
1587b	1 "	2	2	....		Lost.	43 560	.....	.....	.....	.....	....	....	14.5	Under 200 000 pounds per square inch original, shortening = 45.3 per cent.
1587	1 "	12	12	42		.....		43 080	44 710	40 120	28 950 000	3.21	.41		
1583a	1¼ "	2.5	2	....		41 040	41 060	.....	.....	.....	.....	....	....	13. 5	
1583b	1¼ "	2.5	2	....		43 560		.....	.....	.....	.....	....	....	13. 4	
1583	1¼ "	15	12	42	Bent, .05 inch ordinate 6 inches from end	.....		40 060	37 690	36 360	28 920 000	2.13	.59	....	Flexure started in opposite directions at the two ends, at finish is orthodox.
1579a	1⅜ "	3	2	....		42 550	39 317	.....	.....	.....	.....	....	....	13.4	
1579b	1⅜ "	3	2	....		42 930		.....	.....	.....	.....	....	....	13.4	
1579	1⅜ "	18	12	42		.....		38 420	38 920	35 810	.....	1.72	.59		
1575a	1¾ "	3.5	2	....		40 610	38 193								
1575b	1¾ "	3.5	2	....		40 650									
1575	1¾ "	21	12	42		.....		39 450	None.	33 780	.....	2.24	.93	....	Flexed orthodox, very slowly.
1570a	2 "	4	2	....		39 870	39 750								
1570	2 "	24	12	42		.....		39 750	39 650	38 340	.....	2.05	.97		
1567a	2¼ "	4½	2	....		40 240	38 310								
1567b	2¼ "	4½	2	....		39 640									
1567	2¼ "	27	12	42		.....		39 270	None.	34 620	.....	0.48	.32		
1566	2¼ "	40.5	18	63		.....		37 330	"	28 550	.....	0.54	.85	....	Resistance diminished very slowly and gradually.
1453	3 × ⅜ "	4.5	12	42	Heavy hot stamped figures in middle	.....	47 363	47 650	"	45 090	.....	0.67	.04		
1453a	" "	6.75	18	63		.....		46 420	"	38 020	.....	0.32	.07		
1453b	" "	9	24	83		.....		46 150	"	34 480	.....	...	.10	....	Flexed orthodox.
1457	3 × ½ "	6	12	42	Heavy hot stamped figures	.....		41 650	.....	.....	.....	1.17	.14	....	Not held squarely. At 33 050 pounds per square inch had perceptibly deflected. Behavior similar to 1583.
1457a	"	12	24	8		.....	44 417	43 490	.....	.....	.....	0.25	.26		
1457b	" "	15	30	104		.....		42 170	.....	.....	.....	0.20	.28	....	Flexed orthodox. Just before failure deflection = .02 inch.
1461	3 × ¾ "	9	12	42		.....	41 447	43 580	43 350	43 350	.....	2.00	.20	....	Scaled from top downward.
1461a	" "	22	29.3	102	Crooked. Maximum ordinate .02 inch	.....		40 700	None.	26 970	.....	0.18	.28	....	Flexed orthodox.
1465	3 × 1 "	12	12	42	Straight	.....	39 397	41 200	40 610	40 610	.....	1.83	.28	....	"
1465a	" "	24	24	83	Crooked. Maximum ordinate .05 inch	.....		36 920	None.	26 600	.....	0.29	.37	....	Just before failure deflection = .02 inch.
1469	3 × 1¼ "	14	11.2	39	Straight	.....	38 482	38 350	42 980	42 610	.....	2.22	.35		
1469a	" "	22.5	18	63	Gentle curve, .09 inch, ordinate central	.....		35 430	None.	31 300	.....	0.13	.20	....	Flexed orthodox. Just before failure deflection = .03 inch.
1473	3 × 1½ "	18	12	42	" .03 " "	.....	37 820	36 920	37 520	36 790	.....	2.11	.62	....	Flexed orthodox. No perceptible deflection before failure.
1477	3 × 1¾ "	21	12	42	Straight	.....	35 917	35 760	37 580	37 160	.....	1.81	.63	...	Just before failure deflection = .005 inch.
1481	3 × 2 "	24	12	42	"	.....	39 302	37 670	.....	33 740	.....	0.46	.23	....	Flexed orthodox.
1488	4 × ½ "	6	12	42	"	.....		55 420	.....	52 360	.....	2.17	.12	....	Flexed orthodox. At load 50 970 per square inch specimen calipered, and found to have recovered length perfectly.
1488a	" "	9	18	63	"	.....	53 800	55 110	.....	52 950	.....	0.44	.02		
1488b	" "	12	24	83	"	.....		55 320	.....	39 520	.....	0.33	.18	....	Gave way rather suddenly.
1488c	" "	15	30	104	Heavy stamped figures across bar 2 inches from one end										

from rolls).

Laborator[y]	Dime[nsions] of cross[-section]. Inch[es].	Length.	Length.		(from rolls).	Elastic [limit, com]pressio[n, pounds] per sq[uare inch].	Elasti[c limit,] Ten[sion.] See Ta[ble]	Load p[er square] inch a[t]	Second [maximum.] Pounds [per square] in[ch.]	Load p[er square] inch at	Mod[ulus of] elasticity [pounds] per sq[uare inch].	Perman[ent set] ing.	Per[manent] deflectio[n]	Perman[ent set] ing w[ith] pound[s per square] inch.	
1667a	¾ round ...	1.5	2	....	....	47 300	46 090	......	......	......	....	....	....	14.8	
1667	¾ " ...	9.37	12.5	50	....	......		44 980	45 580	......	27 880 000	....	.09	....	Gave way 3 inches from end.
1669a	1 " ...	2	2	....	....	46 170	44 202	......	......	......	....	....	....	14.8	Under 200 000 lbs. per sq. in. original, shortening = 47.0 per cent. This equals 99 550 lbs. per sq. in. actual enlarged area at center.
1669b	1 " ...	2	2	....	....	45 870		......	......	......	....	....	....	14.9	
1669	1 " ...	12	12	48	Gentle curve, .03 inch ordinate central	......		44 000	44 000	33 410	27 590 000	1.25	.38	....	Flexed orthodox.
1551a	1¼ " ...	2.5	2	....	....	42 970		......	......	......	....	...	....	15.2	
1551b	1¼ " ...	2 5	2	....	....	43 950	40 747	......	......	......	....	....	....	15.2	
1551	1¼ " .	15	12	48	Bent, .035 inch ordinate 5 inches from end........	......		40 850	None.	22 060	....	2.67	1.06	...	Flexed orthodox, ends scaled first.
1544a	1½ " ...	3	2	....	....	41 720		......	......	......	....	....	....	15.4	
1544b	1½ " ...	3	2	....	....	40 860	40 275	......	......	......	....	....	....	15.3	
1544	1½ " ...	18	12	48	Straight........	......		41 880	None.	28 870	....	1.78	.78		
1543a	1¾ " ...	3.5	2	....	....	42 870		......	......	......	....	....	....	15.3	
1543b	1¾ " ...	3.5	2	....	....	41 280	40 017	......	......	......	....	....	....	15.3	
1543	1¾ " ...	21	12	48	....	......		39 950	39 910	31 690	....	1.52	.71		
1539a	2 " ...	4	2	....	....	40 620									
1539b	2 " ...	4	2	....	One end shows bruise of shear blade........	37 040	38 207								
1539	2 " ...	24	12	48	....	......		40 850	None.	31 990	....	1.29	.74	....	Flexed orthodox.
1535a	2¼ " ...	4½	2	....	....	38 300									
1535b	2¼ " ...	4½	2	....	....	37 950									
1535	2¼ " ...	27	12	48	....	......	......	36 790	37 130	33 050	....	1.59	.80		
1534	2¼ " ...	40.5	18	72	....	......		36 580	None.	25 500	....	.69			
1530a	2½ " ...	5	2	....	....	35 740									
1530b	2½ " ...	5	2	....	....	37 940									
1530	2½ " ...	30	12	48	....	......	36 100	35 650	None.	32 650	....	1.10	.75	....	Gave way, ends and middle together.
1531	2½ " ...	44	17.6	70	Shows bruise and bend caused by shear blade at one end	......		34 450	None.	26 270	....	.48	.89		
1595a	¾ square ...	1½	2	....	....	44 290		......	......	......	....	....	....	14.6	
1595b	¾ " ...	1½	2	....	....	43 400	44 273	......	......	......	....	....	....	14.4	
1595	¾ " ...	9.37	12.5	45	....	......		44 960	44 210	37 490	27 740 000	1.92	.28	....	Flexed orthodox.
1591a	8/10 " ...	1.6	2	....	....	49 750	47 815	......	......	......	....	....	....	13.9	
1591b	8/10 " ...	1.6	2	....	....	48 360		......	......	......	....	....	....	14.0	
1587a	1 " ...	2	2	....	....	44 025		......	......	......	....	....	....	14.9	
1587b	1 " ...	2	2	....	....	Lost.	43 560	......	......	......	....	....	....	14.5	Under 200 000 pounds per square inch original, shortening = 45.3 per cent.
1587	1 " ...	12	12	42	....	......		43 080	44 710	40 120	28 950 000	3.21	.41		
1583a	1¼ " ...	2.5	2	....	....	41 040		......	......	......	....	....	....	13. 5	
1583b	1¼ " ...	2.5	2	....	....	43 560	41 060	......	......	......	....	....	....	13. 4	
1583	1¼ " ...	15	12	42	Bent, .05 inch ordinate 6 inches from end........	......		40 060	37 690	36 360	28 920 000	2.13	.59	....	Flexure started in opposite directions at the two ends, at finish is orthodox.
1579a	1½ " ...	3	2	....	....	42 550		......	......	......	....	....	....	13.4	
1579b	1½ " ...	3	2	....	....	42 930	39 317	......	......	......	....	....	....	13.4	
1579	1½ " ...	18	12	42	....	......		38 420	38 920	35 810	....	1.72	.59		
1575a	1¾ " ...	3.5	2	....	....	40 610									
1575b	1¾ " ...	3.5	2	....	....	40 650	38 193								
1575	1¾ " ...	21	12	42	....	......		39 450	None.	33 780	....	2.24	.93	....	Flexed orthodox, very slowly.
1570a	2 " ...	4	2	....	....	39 870									
1570	2 " ...	24	12	42	....	......		39 750	39 650	38 340	....	2.05	.97		
1567a	2¼ " ...	4½	2	....	....	40 240									
1567b	2¼ " ...	4½	2	....	....	39 640	38 310								
1567	2¼ " ...	27	12	42	....	......		39 270	None.	34 620	....	0.48	.32		
1566	2¼ " ...	40.5	18	63	....	......		37 330	"	28 550	....	0.54	.85	....	Resistance diminished very slowly and gradually.
1453	3 × ⅜ " ...	4.5	12	42	Heavy hot stamped figures in middle........	......		47 650	"	45 090	....	0.67	.04		
1453a	" " ...	6.75	18	63	....	......	47 363	46 420	"	38 020	....	0.32	.07		
1453b	" " ...	9	24	83	....	......		46 150	"	34 480	....	...	.10	....	Flexed orthodox.
1457	3 × ½ " ...	6	12	42	Heavy hot stamped figures........	......		41 650	......	......	....	1.17	.14	....	Not held squarely. At 33 050 pounds per square inch had perceptibly deflected. Behavior similar to 1583.
1457a	" ...	12	24	83	....	......	44 417	43 490	......	......	....	0.25	.26		
1457b	" " ...	15	30	104	....	......		42 170	......	......	....	0.20	.28	....	Flexed orthodox. Just before failure deflection = .02 inch.
1461	3 × ¾ " ...	9	12	42	....	......	41 447	43 580	43 350	43 350	....	2.00	.20	....	Scaled from top downward.
1461a	" " ...	22	29.3	102	Crooked. Maximum ordinate .02 inch........	......		40 700	None.	26 970	....	0.18	.28	....	Flexed orthodox.
1465	3 × 1 " ...	12	12	42	Straight........	......	39 397	41 200	40 610	40 610	....	1.83	.28	....	"
1465a	" " ...	24	24	83	Crooked. Maximum ordinate .05 inch........	......		36 920	None.	26 600	....	0.29	.37	....	Just before failure deflection = .02 inch.
1469	3 × 1¼ " ...	14	11.2	39	Straight........	......	38 482	38 350	42 980	42 610*	....	2.22	.35		
1469a	" " ...	22.5	18	63	Gentle curve, .09 inch, ordinate central........	......		35 430	None.	31 300	....	0.13	.20	....	Flexed orthodox. Just before failure deflection = .03 inch.
1473	3 × 1½ " ...	18	12	42	" .03 " "	......	37 820	36 920	37 520	36 790	....	2.11	.62	....	Flexed orthodox. No perceptible deflection before failure.
1477	3 × 1¾ " ...	21	12	42	Straight........	......	35 917	35 760	37 580	37 160	....	1.81	.63	...	Just before failure deflection = .005 inch.
1481	3 × 2 " ...	24	12	42	"	......	39 302	37 670	......	33 740	....	0.46	.23	....	Flexed orthodox.
1488	4 × ½ " ...	6	12	42	"	......		55 420	......	52 360	....	2.17	.12	....	Flexed orthodox. At load 50 970 per square inch specimen calipered, and found to have recovered length perfectly.
1488a	" " ...	9	18	63	"	......	53 800	55 110	......	52 950	....	0.44	.02		
1488b	" " ...	12	24	83	"	......		55 320	......	39 520	....	0.33	.18	....	Gave way rather suddenly.
1488c	" " ...	15	30	104	Heavy stamped figures across bar 2 inches from one end, causing a sharp bend, .02 inch ordinate........	......		51 210	......	13 340	....	0.13	.60	....	Gave way very suddenly 5.5 inches from end.
1497	4 × 1 " ...	12	12	42	Straight........	......	41 415	42 630	42 310	41 570	....	2.50	.45		
1497a	" " ...	30	30	104	Slight bend, ordinate .02 inch, near end........	......		39 270	None.	24 890	....	....	....	....	Just before failure deflection = .06 inch. Failed suddenly orthodox.
1500	4 × 1¼ " ...	15	12	42	....	......	36 680	39 300	38 700	38 700	....	1.73	.46	....	No perceptible deflection before failure.
1500a	" " ...	30	24	83	Gentle curve, 04 inch ordinate........	......		38 200	None.	27 530	....	0.20	.40	....	Gave way suddenly, orthodox. Just before failure deflection = .01 inch.
1503	4 × 1½ " ...	18	12	42	Straight........	......		39 500	40 640.	40 640	....	2.05	.45	....	No perceptible deflection before failure.
1503a	" " ...	26.9	18	63	Slight bend, ordinate .02 inch, at 6 inches from end.	......	37 580	39 850	None.	32 920	....	0.33	.27	....	Gave way first at the bend.
1503	" " ...	45	30	104	Slight bend, ordinate .025 inch, at 6 inches from end.....	......		39 100	None.	32 920	....	0.11	.70	....	Just before failure deflection = .03 inch.

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TABLE No. 2.

Tensile Tests of Steel Bars. Pieces Cut from Same Bars used in Compression Tests, Table No. 1.—Testing Laboratory of Cambria Iron Company May, 1886. C. A. Marshall, Engineer of Tests.

No. of tests in average.	Dimensions of cross-section. Inches.	Elastic limit. Lbs. per sq. in.	Ultimate strength. Lbs. per sq. in.	Length on which elongation is given. Inches.	Per cent. elongation.	Per cent. reduction of area.	Modulus of elasticity. Lbs. per sq. in.	Character of fracture.	Remarks.
4	¾ round.	46 090	68 995	8	26.3	48.2	28 980 000	Silky and dull.	One test only for modulus.
4	1 "	44 202	67 970	10	25.7	41.5	.....	Dull crystalline and dull.	
3	1¼ "	40 747	67 040	12	26.8	46.9	.....	Dull.	
3	1½ "	40 275	66 363	15	25.8	41.9	.....	Dull crystalline and dull.	
3	1¾ "	40 017	66 334	18	24.0	33.6	.....	Two silky, one dull crystalline and dull.	
3	2 "	38 207	65 663	20	23.9	27.8	.....	One silky, two crystalline.	
1	2¼ "	37 000	65 460	22	19.9	17.2	.....	Crystalline.	
1	2½ "	36 100	.....	25	10.2	.. ..	.....	.....	Not broken with 61 180 pounds per square inch.
3	¾ square.	44 273	68 427	8	26.5	42.5	.....	Silky, some dull crystalline.	
2	$\frac{7}{10}$ "	47 815	69 390	8	24.9	38.9	.....	Silky and dull.	
3	1 "	43 560	68 510	10	25.6	37.1	.....	Silky and dull crystalline.	
3	1¼ "	41 060	67 973	12	26.0	39.2	.....	Dull and dull crystalline.	
3	1½ "	39 317	66 833	15	25.1	36.8	.....	Silky, some crystalline.	
3	1¾ "	38 193	66 409	18	24.6	33.0	.....	Crystalline, dull center.	
1	2¼ "	38 310	.....	22	7.6	....	.....	.....	Not broken with 60 050 pounds per square inch.
3	3 × ⅜	47 363	68 657	15	27.0	44.0	{29 350 000 29 640 000}	Silky.	Two tests for modulus on strips.
3	3 × ½	44 417	67 527	15	26.5	42.8	.....	90 per cent. silky, 10 per cent. faint crystalline.	
3	3 × ¾	41 447	66 987	18	25.6	39.1	.....	75 per cent. silky, 25 per cent faint crystalline.	
3	3 × 1	39 397	66 700	18	24.9	35.9	.....	40 per cent. silky, 60 per cent. dull crystalline.	
4	½ × 1¼	38 482	66 640	8	26.4	45.9	.....	Silky and dull.	Strips cut from 3 × 1¼-inch bar.
4	½ × 1½	37 820	66 342	8	21.7	31.1	{29 410 000 29 860 000}	Silky and crystalline.	" 3 × 1½ " 2 tests for modulus.
4	$\frac{7}{10}$ × 1¾	35 917	65 762	8	27.6	44.1	.....	Three silky, one part crystalline.	" 3 × 1¾ " "
4	⅜ × 2	39 302	66 537	8	26.4	46.6	.....	Silky.	" 3 × 2 " "
2	4 × ½	53 800	71 255	20	21.0	36.9	.....	Silky.	Bar finished at very low heat.
3	4 × ¾	41 527	66 917	20	24.5	35.1	.....	25 per cent. silky, 75 per cent. crystalline.	
2	4 × 1	41 415	66 230	22	24.3	36.5	.....	25 per cent. silky, 75 per cent. crystalline.	
1	4 × 1¼	36 680	.....	..	....	....	.....	.....	Not broken. Beyond capacity of machine.
1	4 × 1½	37 580	.....	..	....	....	.....	.....	" " " "

All tested full size as from rolls except where noted.

TABLE No. 3.

Compression Tests of Iron Bars.—Testing Laboratory of Cambria Iron Company, June, 1886. C. A. Marshall, Engineer of Tests.

1. Laboratory No.	2. Dimensions of cross-section. Inches.	3. Length. Inches.	4. Length. Diameters.	5 $\frac{l}{r}$	6. Condition of piece before test.	7. Elastic limit compression, Lbs. per square inch.	8. Elastic limit tension. See Table 4	9. Load per square inch at failure.	10. Second maximum. Pounds per square inch.	11. Load per square inch at removal.	12. Modulus of elasticity, Pounds per square inch.	13. Permanent shortening. Per cent.	14. Permanent deflection. Inches.	15. Permanent shortening with 100 000 lbs per sq. in. Per cent.	16. Remarks.
2158	½ round....	9.5	12.7	51	Fairly straight.....	.....	35 530	36 750	35 640	32 300	26 160 000	1.3	.28	.....	Bent orthodox.
2159	"	9.5	12.7	51	" "	.....		36 750	36 970	30 070	26 240 000	1.5	.35	.....	"
2162	1 "	12	12	48	" "	.....		36 210	37 270	37 270	26 440 000	0.83	.25	.....	"
2163	1 "	12	12	48	" "	.....		36 580	37 370	37 370	26 350 000	0.75	.22	.....	"
2166	1 "	30	30	120	Sharp bend 5 inches from end; ordinate at that point = .08.....	.....	36 170	31 580	None.	18 460	.....	0.10	.30	.....	Failed at the bend.
2164	1 "	2	2	....	.....	36 890	.....	.....	.....	.....	.....	....	...	20.25	At 100 000 lbs. per sq. in. Specimen skewed.
2196	½ square....	9.5	12.7	44	Fairly straight.....	.....	32 975	34 590	34 590	33 870	27 420 000	2.0	.28	.....	Bent orthodox.
2197	"	9.5	12.7	44	" "	.....		32 790	31 520	30 780	27 790 000	1.7	.30	.....	"
2168	1 "	12	12	42	" "	.....		33 250	36 500	36 500	27 300 000	1.4	.22	.....	"
2169	1 "	12	12	42	" "	.....	32 800	33 550	34 720	34 720	27 990 000	1.33	.29	.....	"
2172	1 "	30	30	104	Gentle curve .03 inch, ordinate central.....	.....		30 680	None.	18 750	.....	0.16	.35	.....	Failed orthodox in direction of initial bend.
2174	1½ "	18	12	42	Fairly straight.....	.....	25 560	27 290	30 140	30 140	....	1.3	.48	.....	
2175	1½ "	27	18	62	Straight.....	.....		25 970	None.	22 080	.....	0.8	.70	.....	Failed orthodox.
2177	2 "	24	12	42	Gentle curve, .03 inch, ordinate central.....	.....	26 930	27 170	31 360	31 360	.....	1.3	.62	.....	Bent orthodox.
2214	3 × ½.....	6	12	42	Straight.....	.....	28 165	30 070	38 040	38 040	.....	1.8 *	.11	.....	"
2215	"	12	24	83	"	.....		28 360	None.	19 610	....	0.6	.30	.....	"
2217	"	15	30	104	Fairly straight.....	.....		27 710	None.	19 610	.....	0.3	.22	.....	"
2219	"	18	36	125	Ordinate .02 inch, along middle 10 inches.....	.....		27 640	None.	19 610	.....	0.1	.18	.....	"
2191	2 13/16 × 1¼.....	15	12	42	Straight.....	.....	26 470	27 570	31 940	31 940	.....	2.3	.28	.....	"
2192	"	30	24	83	Gentle curve, .04 inch, ordinate central.....	.....		26 510	None.	20 560	.....	0.23	.34	.....	"
2194	3.2 × 1¼.....	21	12	42	Straight.....	.....	27 430	27 700	32 570	32 570	.....	1.6	.43	.....	"

TABLE No. 4.

Tensile Tests of Iron Bars—Testing Laboratory of Cambria Iron Company, June, 1886.
C. A. Marshall, Engineer of Tests.

Laboratory No.	Dimensions of cross-section. In.	Elastic limit. Lbs. per sq. in.	Ultimate Strength. Lbs. per sq. in.	Length on which elongation is given.	Per cent. elongation.	Per cent. reduction of area.	Modulus of elasticity. Lbs. per sq. in.	Character of fracture.	Remarks.
2157	¾ round.	35 640	55 060	8	19.5	28.3	27 500 000	Dark silky.	
2160	¾ "	35 420	54 620	8	20.4	29.1	27 410 000	"	
2161	1 "	35 520	53 400	10	12.4*	19.0	26 700 000	Bright short fibrous.	*Not including fracture. Broke at an injury near grip.
2165	1 "	36 820	56 300	10	20.0	26.4	27 540 000	Bright short fibrous. Specks granular.	
2195	¾ square.	32 610	49 930	8	27.7	35.9	28 990 000	Dark silky.	
2198	¾ "	33 340	49 270	8	21.6	35.8	29 180 000	"	
2167	1 "	32 550	51 220	10	26.4	32.0	27 900 000	"	
2171	1 "	33 050	51 340	10	27.4	41.5	28 290 000	"	
2173	1½ "	25 560	47 020	15	25.5	34.4	.....	Laminated fibrous.	
2176	2 "	26 930	47 520	18	15.1	20.3	.....	Banded fibrous, 5 per cent. granular.	
2213	3 × ½	27 970	49 220	15	19.4	27.7	.....	Short fibrous.	
2218	3 × ½	28 360	49 480	15	22.8	28.4	.....	"	
2190	2⅛ × 1¼	26 470	47 530	20	24.1	27.1	.....	Laminated, dark fibrous	
2193	3.2 × 1⅜	27 430	43 850	24	7.8	12.9	.....	Coarse fibrous, sliver on edge.	

Many of the bars are rough. All tested full size as from rolls.

TABLE No. 7.

Compression Tests of Steel and Iron Bars 1 inch square by 12 inches long. Bars marked W all from same blow of 70 000-pound Cambria Bessemer Steel. Bars marked K all from same lot of Union Iron Mills Iron.

Flat or hinged ends	Bar mark.	Elastic limit. Lbs. per sq. in.	Maximum resistance. Lbs. per sq. inch.	Load at removal.	Chord shortening. Per cent.	Deflection.	Remarks.
						Inch.	
Flat	W 1	49 720	50 220	40 000	2.66	.36	Deflection orthodox.
"	W 2	48 400	49 200	40 000	2.83	.39	"
"	W 3	49 070	49 070	45 000	1.42	.10	"
"	W 4	49 700	51 790	45 000	2.66	.36	Bent in reverse curve.
"	W 5	47 880	47 880	47 280	1.00	.26	Scale disturbed at ends first, removed as soon as scale much disturbed in middle.
"	W 6	50 200	50 790	45 000	1.50	.16	Deflection orthodox.
"	W 7	48 170	49 260	45 000	2.17	.14	
"	W 9	50 170	51 160	45 000	1.66	.20	
		49 164	49 921	.....	....	....	Average.
Hinged	W 5	51 350	51 350	45 000	2.75	.09	
"	W 8	47 480	48 470	36 000	1.33	.32	
		49 415	49 910	.....	....	....	Average.
Flat	K 1	35 100	38 220	38 220	1.66	.21	
"	K 2	35 600	38 270	38 270	1.25	.24	
"	K 3	35 500	39 500	39 400	1.50	.20	
"	K 5	34 340	38 150	38 150	1.50	.18	
"	K 6	36 410	38 780	38 780	1.33	.25	
"	K 7	33 680	35 730	35 730	1.33	.25	
"	K 8	31 760	36 840	36 840	1.50	.19	
"	K 9	36 000	39 400	39 400	1.42	.20	
Hinged	K 11	33 380	37 650	37 650	1.66	.17	Bent along axis.
Flat	K 13	32 520	.....	32 520	0.66	.03	When scaled all along.
		.....	36 220	36 220	1.58	.20	
"	K 14	33 860	37 440	37 440	1.42	.21	
"	K 15	33 960	36 430	36 430	1.25	.22	
"	K 16	34 410	.....	34 410	0.66	.04	When scaled all along.
		.....	36 630	36 630	1.42	.20	
"	K 17	34 180	36 200	36 200	1.33	.23	
"	K 18	34 750	.....	34 750	0.66	.09	When scaled all along in 5 minutes.
		.....	37 560	37 560	1.17	.24	
"	K 19	32 300	.....	32 300	0.75	.12	When scaled all along.
		.....	34 000	34 000	1.42	.24	
"	K 20	33 400	36 340	36 340	1.50	.25	
		34 185	37 256	.....	....	....	Average.
Hinged	K 4	32 900	32 900	32 000	....	.15	
"	K 10	34 180	36 000	36 000	1.08	.16	
"	K 12	34 240	37 840	37 840	1.50	.22	
		33 773	35 580	.....	....	....	Average.

TABLE No. 5.

Compression Tests of Miscellaneous Bars. – Testing Laboratory of Cambria Iron Company, 1886. C. A. Marshall, Engineer of Tests.

1 Laboratory No.	2 Dimensions of cross-section. Inches.	3 Length. Inches.	4 Elastic limit compression. Lbs per sq. in.	5 Elastic limit tension. Lbs. per sq. in.	6 Load per sq. in. at failure. Lbs.	7 Second maximum. Lbs. per sq. in.	8 Load per sq. in. at removal. Lbs.	9 Modulus of elasticity. Lbs. per sq. in.	10 Permanent shortening. Per cent.	11 Permanent deflection. Inches.	12 Permanent Shortening with 100 000 pounds per sq. in. Per cent.	13 Kind of material.	14 Remarks.
331	1 round	12	....	41 230	42 000	None.	30 000	29 740 000	2.9	.50	.....	Open hearth steel, all from same melt.	
330	1 "	12	....		42 480	43 120	30 000	.....	1.8	.46	.....		
348	1/16 square	9.62	....	42 830	43 160	42 000	30 000	29 010 000	3.5	.58	.....		Gave way at a bend 2 inches from middle.
352	1/16 "	9.62	....		43 900	None.	30 000	.....	2.8	.60	.....		
350	1 square	12	....	39 570	39 990	38 910	30 000	.....	3.1	.74	.....		
358	1 "	12	....		40 390	40 080	30 000	.....	3.2	.64	.....		
359	.799 r'd turned from .8 square	2.39	42 000	42 830	....	....	....	.....	..	..	.1587		Maximum stress per square inch original = 113 200. " " actual = 89 460.
457	1/4 round	9.37	....	54 430	53 960	50 380	50 380	29 420 000	0.9	.20	.....	Open hearth steel, all from same melt.	Gave way at injury by clutch.
454	1/4 "	9.37	....		53 130	49 210	49 210	.....	0.9	.21	.....		" "
476	1 round	12	....	50 830	51 500	49 920	49 920	29 420 000	1.0	.28	.....		
479	1 "	12	....		49 500	50 270	50 270	29 200 000	1.0	.28	.....		
466	5/16 square	9.62	....	51 810	51 000	59 980	59 980	28 670 000	1.7	.23	.....		
503	5/16 "	9.62	....		51 250	57 650	57 650	.....	2.0	.34	.....		
500	1 square	12	....	49 260	48 240	57 340	57 340	.....	2.0	.45	.....		
506	1 "	12	....		48 340	58 080	58 080	.....	1.8	.39	.....		
510	.94 r'd turned from 1 round.	2.84	50 000	50 830	....	....	....	.....	..	..	.0426		Maximum stress per square inch, original = 168 700. " " actual = 126 350.
573	5/16 square	9.62	68 000	69 000	....	88 720	88 720	29 220 000	1.0	.20	.....		Elastic limits by micrometer. Beam showed limit of 573 at 73 260 lbs., and of 579 at 72 000 lbs., but there was no failure to sustain those loads. There was but one maximum corresponding to second maximum as given for the other materials.
579	5/16 "	9.62	69 000		....	89 420	89 420	29 350 000	1.0	.24	.....		
559	1 round	12	67 000	67 110	....	79 110	79 110	29 330 000	0.8	.21	.....	Open hearth steel, all from same melt.	Elastic limits by micrometer. Beam failed to show limit. But one maximum.
547	1 "	12	67 500		....	79 110	79 110	29 200 000	0.75	.22	.....	Spring steel.	
547a	.94 r'd turned from 1 round.	2.83	70 000		....	....	....	.....	..	..	.0065		Maximum stress per square inch, original = 190 000. " " actual = 166 030.
2336a	1 round	12	49 500	49 750	....	....	....	.....	2.54	.61	.....	Open hearth steel.	
2336b	.94 r'd turned from 1 round.	2.84	48 000		49 500	48 000	35 600	28 830 000	..	..	.0985		Maximum stress per square inch, original = 125 000. " " actual = 99 360.
2348a	1 round	12	....	32 670	30 220	30 090	22 800	.....	2.5	.35	.....	O. H. steel.	
2351a	1 "	12	....	44 690	43 690	None.	35 000	.....	1.2	.31	.....	"	
2352a	1 "	12	....	43 250	44 000	40 000	40 000	30 490 000	1.0	.15	.....	"	
2353a	1 "	12	....	46 000	45 750	None.	35 000	.....	1.6	.40	.....	"	
2350a	1 "	12	....	48 160	47 520	46 390	35 000	.....	2.5	.57	.....	"	
2335a	1 "	12	....	50 600	49 020	49 270	40 000	.....	1.7	.36	.....	"	
2343a	1 "	12	....	32 010	32 650	33 650	30 000	.....	1.6	.11	.....	Bessemer steel.	
2344a	1 "	12	....	36 920	37 820	None.	30 000	.....	1.5	.36	.....	"	
2347a	1 "	12	....	39 460	41 510	"	35 000	.....	1.2	.24	.....	"	
2346a	1 "	12	....	39 570	41 720	40 460	35 000	.....	1.2	.17	.....	"	
2345a	1 "	12	....	40 000	39 500	None.	30 000	29 790 000	1.8	.42	.....	"	
2338a	1 "	12	....	47 780	46 260	"	35 000	.....	1.4	.42	.....	"	
2337a	1 "	12	....	47 000	45 500	"	35 000	29 810 000	1.6	.45	.....	"	
2293	1 "	12	....	47 600	48 500	42 810	35 000	29 240 000	1.8	.46	.....	"	
2307	1 "	12	....	39 000	40 000	36 600	25 000	28 570 000	2.3	.72	.....	Iron rolled from scrap.	
2309	1 "	12	....	36 000	38 000	36 500	25 000	28 570 000	2.2	.58	.....		
2311	1 "	12	....	42 780	38 500	35 580	25 000	28 180 000	1.7	.56	.....		
2309a	.94 r'd turned from 1 round.	2.83	38 000	36 000	....	....	....	.....	....	....	.....		Maximum stress per square inch, original = 91 710. " " actual = 73 850.
2391a	3/4 round	9.06	....	35 500	36 500	36 940	30 000	29 910 000	4.0	.46	.....	Sligo stay-bolt iron.	
2391b	.80 r'd turned from 3/4 round	3.5	36 000		38 000	48 910	48 910	30 120 000	9.0	.23	.....		
2391c	.80 r'd turned from 3/4 round	2.49	34 000										Maximum stress per square inch, original = 80 000. " " actual = 67 070.

TABLE No. 6.

Tensile Tests of Miscellaneous Bars.—Testing Laboratory of Cambria Iron Company. C. A. Marshall, Engineer of Tests.

1 Laboratory No.	2 Lab. Nos. of compression tests from same lot.	3 Dimensions of cross-section.	4 Elastic limit. Lbs. per sq. in.	5 Ultimate strength. Lbs. per sq. in.	6 Gauged length.	7 Elongation. per cent.	8 Reduction of area per cent.	9 Modulus of Elasticity. Lbs. per sq. in.	10 Appearance of fracture.	11 Kind of material.	12 Remarks.
		Inch.			In.						
329	330, 331	1 round.	41 230	67 320	10	28.7	59.4	30 420 000	Fine silky	O. H. steel from same melt.	
346	348, 352, 350	⅞ square.	42 830	67 500	8	29.5	57.0	29 850 000	Cup, fine silky		
357	358, 359	1 square.	39 570	66 120	10	27.8	57.4	.....	Silky		
455	457, 454	¾ round.	54 430	102 300	8	19.4	30.9	29 150 000	Fine crystal, dull center.	O. H. Steel from same melt.	
484	476, 479, 466	1 "	50 830	101 900	10	14.9	25.4	29 500 000	" " " spot		
497	503, 500	⅞ square.	51 810	102 200	8	17.2	28.9	29 640 000	Crystal, dull spot		
512	506, 510	1 "	49 260	101 600	10	14.0	18.8	29 960 000	Crystalline		
576	573, 579	⅞ "	74 510	144 400	8	7.2	10.2	29 420 000	"	O. H. steel from same melt.	Elastic limit by beam and flaking of scale.
574		1 "	69 000	144 700	8	7.0	8.0	29 200 000	"		" " micrometer.
549	559, 547, 547a	1 round.	67 110	144 600	10	9.3	10.7	29 580 000	"		" " " beam failed to show limit.
2336	2336a—b	1 "	49 750	80 825	10	27.0	47.0	29 630 000	Dull crystal, dull spot	O H. steel.	
2348	2348a	1 "	32 670	45 980	10	34.1	69.6	.....	Half cup, silky	"	
2351	2351a	1 "	44 690	71 400	10	26.2	56.0	.....	Cup, silky	"	
2352	2352a	1 "	43 250	74 625	10	25.0	55.3	29 960 000	" "	"	Each from a different melt.
2353	2353a	1 "	46 000	78 375	10	25.4	52.4	.....	Silky and dull	"	
2350	2350a	1 "	48 160	82 150	10	21.2	47.8	.....	Dull	"	
2335	2335a	1 "	50 660	83 430	10	22.4	52.2	.....	Silky and dull	"	
2343	2343a	1 "	32 010	52 100	10	33.6	64.6	.....	"	Bessemer steel.	
2344	2344a	1 "	36 920	61 110	10	27.6	63.4	.....	"	"	
2347	2347a	1 "	39 460	61 870	10	29.4	60.1	.....	" and dull	"	
2346	2346a	1 "	39 570	63 140	10	29.2	54 2	.....	"	"	Each from a different heat.
2345	2345a	1 "	40 000	64 680	10	27.5	58.0	30 420 000	" and dull	"	
2338	2338a	1 "	47 780	72 050	10	18.1	—	.....	Dull, some faint crystal	"	Broke in grip.
2337	2337a	1 "	47 000	74 625	10	23.2	46.0	30 370 000	" crystal, dull center	"	
2292	2293	1 "	47 600	74 650	10	23.3	52.1	.....	" " " "	"	
2306	2307	1 "	39 000	56 810	10	21.0	30.0	28 570 000	Coarse silky	Iron rolled from scrap.	
2308	2309	1 "	36 000	51 790	10	21.8	53.8	28 480 000	Dark "		
2310	2311	1 "	41 000	57 690	10	15.2	38.4	28 480 000	" "		Elastic limit by micrometer.
2310	2311	1 "	42 780								" " beam.
2390	2391a-b-c	1 "	35 500	55 890	9	29.7	54.4	30 190 000	Half cup, fine silky	Sligo stay-bolt iron.	

TABLE No. 8.

Compression Tests of 1-inch Square Steel Bars, Hinged.

(*See Plate X.*)

All from same blow, distinguished by letter W. Tested as from rolls with rocking bearings, bars vertical, axis of pins east and west. All dimensions in inches; loads in pounds per square inch. "Deviation" is from straight line through centers of ends of bars at the middle of length.

Piece mark and Rod number.	Length.	$\frac{l}{r}$ ratio.	Condition before Test.			Elastic limit from Table No. 7.	Maximum resistance.	Difference maximum —Elastic limit.	Principal deviation just before failure.	Just after failure.		Load removed. Deviation.	Maximum resistance upon reapplying load.	Maximum shortening per inch.	Total chord shortening.	Remarks. Mode of failure, etc.
			Twist, Arc for radius 1.	Deviation towards N. or S.	Deviation towards E. or W.					Load.	Deviation.					
W 9·	16	55	.....	00	00	50 170	49 380	−790	.....	41 720	.....	N. .30	.....	.....	.14	Not removed till load fallen to 30 000.
W 9:	16	55	.....	00	00	50 170	50 170	000	.....	39 730	.....	N. .30	.....	.....	.22	" "
W 9·	20	69	.....	00	00	50 170	50 720	+550	.....	32 690	.....	S. .31	.....	.....	.195	Rather sudden at 6 inches from upper end.
W 9:	20	69	.....	00	W. .01	50 170	51 110	+940	.....	19 810	.....	S. .30	.....	.....	.055	Slowly to 38 720; then suddenly to 19 810.
W 9·	22	76	.....	S. .03	W. .02	50 170	48 380	−1 790	.....	26 830	.....	S. .31	.....	.....	.035	Sudden.
W 9:	22	76	.....	S. .04	W. .04	50 170	45 300	−4 870	.....	21 850	.....	S. .36	.....	.....	.04	"
W 5·	24	83	.....	.00	E. .01	49 610	49 060	−550	.....	19 900	.....	S. .44	.....	.01	.05	" Elastic limit is mean of two tests.
W 5:	24	83	.....	N. .02	W. .01	49 610	48 950	−660	.....	19 900	.....	N. .44	.....	.015	.05	"
W 8·	26	90	.....	S. .02	00	47 480	46 950	−530	.....	18 820	.....	S. .45	.....	.012	.05	"
W 8:	26	90	.....	00	W. .02	47 480	49 260	+1 780	.....	18 820	.....	S. .45	.....	.....	.05	" after standing a while at maximum.
W 8·	28	97	.....	N. .02	E. .02	47 480	47 720	+240	.....	33 000	.....	{N. .20 / E. .75}	.....	.025	.08	" bent along axis.
W 8:	28	97	.....	N. .01	W. .02	47 480	46 480	−1 000	.....	17 580	.....	S. .57	.....	.007	.04	"
W 2·	30	104	.....	S. .02	W. .02	48 400	47 670	−1 730	.....	13 930	.....	N. .57	.....	.01	.06	"
W 2:	30	104	.....	S. .02	00	48 400	45 370	−3 030	.....	15 120	.....	S. .62	.....	.015	.04	"
W 8·	32	111	.....	00	E. .02	47 480	46 360	−1 080	.....	16 450	.....	S. .56	.....	.01	.04	Very sudden.
W 8:	32	111	.02	N. .02	W. .03	47 480	45 650	−1 830	N. .08	15 900	N. > .98	N. .60	.....	.02	.04	
W 6·	34	118	.....	00	00	50 200	45 560	−4 640	.....	15 780	.....	S. .54	.....	.01	.03	Very sudden.
W 6:	34	118	.....	N. .03	W. .02	50 200	44 620	−5 580	N. .10	15 800	N. .89	N. .64	.....	.015	.04	
W 8·	36	125	.10	S. .025	W. .02	47 480	34 660	−12 820	.....	15 100	.....	S. .32	.....	.....	.01	
W 8:	36	1 5	Some.	N. .06	E. .03	47 480	31 680	−15 800	N. .15	16 000	N. .74	N. .28	.....	.005	.01	
W 7.	38	132	.....	S. .01	W. .03	48 170	41 690	−6 480	N. .11	13 600	N. > .90	N. .43	.....	.01	.02	
W 7:	38	132	.....	N. .015	W. .03	48 170	43 280	−4 890	.....	12 960	.....	{E. .52 / N. .32}	.....	.01	.07	Bent east first, then north.
W 8·	40	138	.....	S. .015	W. .03	48 170	37 980	−10 190	S. .045	13 000	S. .97	S. .43	.....	00	.01	Very sudden. Scale disturbed only near middle.
W 5·	40	138	.....	N. .08	E. .015	49 610	19 210	−32 140	N. .15	15 900	N. .59	N. .12	15 400	00	00	Scale disturbed middle 12 inches.
W 7·	42	145	.06	00	W. .01	48 170	34 000	−14 170	S. .03	13 600	S. .85	S. .23	>11 800	.004	00	Maximum lengthening per inch middle S. = .005.
W 7:	42	145	.....	N. .05	00	48 170	16 600	−31 570	S. .10	14 600	S. .39	S. .05	15 800	00	00	Scale disturbed in middle 12 inches by reapplication.
W 7·	44	152	.06	N. .06	W. .02	48 170	26 000	−22 170	N. .12	12 100	N. .82	N. .16	12 700	.002	00	Scale disturbed in middle by reapplication.
W 7:	44	152	.....	S. .025	E. .01	48 170	30 000	−18 170	S. .06	12 200	S. .87	S. .16	>12 000	00	00	Scale slightly disturbed N. side middle 15 inches.
W 6·	48	166	.....	N. .02	W. .03	50 200	13 130	−37 070	N. .40	11 540	N. .52	N. .02	13 980	.....	.....	Scale not disturbed.
Same shifted on bearings .02 south of axis						50 200	22 870	−27 330	N. .08	11 440	N. .77	N. .04	16 810	00	00	Scale slightly disturbed middle 6 inches S. side.
W 6:	48	166	.05	N. .06	E. .04	50 200	10 660	−39 540	N. .92	10 660	N. .92	N. .15	9 850	00	00	Scale disturbed middle 14 inches by reapplication.
W 9·	52	180	.....	N. .04	W. .02	50 170	9 810	.....	N. .11	9 210	N .42	N. .04	9 510	00	00	Scale not disturbed.
Same shifted on bearings .02 south of axis						50 170	13 270	.....	N. .13	9 810	N. .54	N. .05	.....	00	00	"
" .04 "						50 170	18 810	.....	N. .13	9 810	N. .79	N. .05	.....	00	00	"
" .06 "						50 170	20 600	.....	{N. .04 / W. .06}	9 710	S. .72	N. .04	13 870	00	00	"
W 9:	52	180	.....	00	E. .02	50 170	12 420	.....	N. .07	9 830	N. .42	00	.....	.....	.....	Scale not disturbed.
Same applying pressure at start to cause failure in opposite direction						.....	29 810	.....	S. .08	10 830	S. 1.06	S. .09	9 730	.002	00	Scale slightly disturbed middle 14 inches north side.
W 6·	56	194	.....	S. .09	E. .03	50 200	8 400	.....	S. .54	8 000	S. .56	S. .11	.....	.....	.....	Scale not disturbed.
Same shifted on bearings .09 north of axis						50 200	8 800	.....	S. .03	8 200	N. .21	S. .08	.....	.....	.....	"
" .06 "						50 200	18 900	.....	S. .16	8 700	S. .94	S. .09	.....	.....	.....	"
" .07 "						50 200	20 000	.....	S. .22	8 800	S. .99	S. .09	.....	00	00	"
W 4·	60	208	.....	S .06	E. .03	49 700	8 000	.....	S. .08	7 200	S. .41	S. .17	8 000	.....	.....	"
Same shifted on bearings .06 north of axis						49 700	10 000	.....	S. .02	7 300	N. .47	S. .04	.....	.....	.....	"
" .04 "						.....	17 900	.....	S. .11	7 300	S. .97	S. .07	.....	00	00	"

TABLE No. 9.

Compression Tests of 1-inch Square Iron Bars, Hinged.

(See Plate XI.)

All from same lot of iron distinguished by letter K. Tested as from rolls with rocking bearings, bars vertical, axis of pins east and west. All dimensions in inches; loads in pounds per square inch. "Deviation" is from straight line through centers of ends of bars at middle of length.

Piece mark and rod number.	Length.	$\frac{l}{r}$ ratio.	Condition before test. Twist. Arc for radius 1.	Deviation towards N. or S.	Deviation towards E. or W.	Elastic limit from Table No. 7.	Maximum resistance.	Difference maximum — elastic limit.	Principal deviation just before failure.	Just after failure. Load.	Just after failure. Deviation.	Load removed. Deviation.	Maximum resistance upon reapplying load.	Maximum shortening per inch.	Total chord shortening.	Remarks. Mode of failure, etc.
K —*	16	55	....	S. .01	W. .01	.....	34 700	.....	.....	.....	.....	S. ..	.....	.015	.11	Load at removal 22 000.
K —:	16	55	....	N. .01	W. .015	.....	34 300	.....	W. .065	32 000	W. .075	W. .303*	.....	.025	.13	Bent along axis. * After load fallen to 30 900.
K 1*	20	69	....	00	W. .02	35 100	34 910	— 190	{W. .10 / S. .04}	30 000	{W. .17 / S. .05}	{W. .44* / S .12*}	.....	.02	.10	" * " 25 000.
K 1:	20	69	....	00	00	35 100	33 910	— 1 190	S. .03	31 500	S. .08	S. .28*	19 000*	.02	.04	* After load fallen to 20 000.
K 1*	22	76	....	N. .025	00	35 100	33 910	— 1 190	N. .035	19 940	N. .355	N. .365*	.....	.015	.04	* " " 18 000.
K 1:	22	76	.04	S. .015	00	35 100	34 700	— 400	.....	18 000	S. ..	S. .34	.....	.015	.04	
K 11*	24	83	....	S. .04	W. .02	33 380	31 230	— 2 150	S. .09	16 850	S. .40	S. .42*	> 10 000	.01	.04	* After load fallen to 16 000.
K 11:	24	83	.04	N. .04	E. .01	33 380	32 220	— 1 160	.....	17 850	N. ..	N. .33	.....	.015	.03	
K 2*	26	90	....	S. .02	W. .02	35 600	33 750	— 1 850	S. .05	14 590	S .56	S. .38	> 13 000	.015	.04	
K 2:	26	90	.03	S. .02	W. .02	35 600	33 450	— 2 150	.....	16 870	S. ..	{W. .24 / S. .30}	.....	.015	.05	Bent west first, load falling to 26 200, then south suddenly, load falling to 16 870.
K 3*	28	97	....	S. .02	E .05	35 500	32 000	— 3 500	{E. .09 / S. .08}	14 000	{E. .25 / S. .61}	S. .41	> 13 000	.015	.05	Started to bend east, then veered south.
K 3:	28	97	....	N. .06	W. .04	35 500	30 700	— 4 800	N. .095	13 900	N. .63	N. .42	> 13 400	.015	.03	Sudden.
K 5*	30	104	.06	S. .06	00	34 340	29 270	— 5 060	S. .12	12 780	S. .65	S. .44	11 710	.01	.05	
K 18*	30	104	....	N. .03	W. .02	34 750	33 000	— 1 750	N. .05	12 000	N. .73	N. .50	> 11 000	.01	.03	
K 3*	32	111	....	N. .04	E. .02	35 500	31 350	— 4 150	.....	12 940	N. ..	{W. .40 / N. .30}	.....	.015	.08	Bent west first, load falling to 24 880, then north suddenly, load falling to 12 940.
K 3:	32	111	.06	00	E. .02	35 500	34 900	— 600	S. .05	13 000	S. .50	{E. .31 / S. .26}	13 500	.01	.05	Sudden.
K 4*	34	118	....	00	W. .04	32 900	30 940	— 1 960	S. .04	9 980	S. .76	S. .44	> 9 780	.01	.02	
K 4:	34	118	.03	S. .05	E. .04	32 900	26 000	— 6 900	S. .13	12 200	S. .57	S. .40	12 500	.004	.03	Slow.
K 4*	36	125	.03	S. .06	W. .03	32 900	20 900	— 12 000	S. .13	13 930	S. .53	S. .20	12 920	.01	.01	
K 4:	36	125	....	N. .03	W. .04	32 900	19 900	— 13 000	.....	11 140	N. .64	N. .30	11 240	.007	.02	Rather slow.
K 5*	38	132	....	00	W. .03	34 340	31 020	— 3 320	N. .03	9 170	N. > .90	N. .57	> 7 000	.01	.04	Sudden.
K 5:	38	132	....	S. .02	E. .02	34 340	23 320	— 11 020	S. .07	11 220	S. .60	S. .24	11 510	.007	.01	"
K 5*	40	138	.10	00	00	34 340	30 600	— 3 740	N. .04	8 950	N. .88	N. .43	> 8 950	.005	.01	"
K 14*	40	138	....	00	W. .03	33 860	18 890	— 14 970	N. .07	11 430	N. .49	N. .11	11 630	.002	.01	Rather sudden.
K 6*	42	145	....	00	W. .04	36 410	18 000	— 18 410	N. .04	12 700	N. .43	N. .02	13 000	00	.01	
K 6:	42	145	....	N. .04	E. .04	36 410	14 600	— 21 810	N. .09	12 910	N. .39	N. .05	.....	....	....	Very slow. Scale not disturbed.
Same shifted on bearings .03 south of axis.....							36 410	21 850	— 14 560	N. .11	10 730	N. .74	N. .22	10 630	.002	.01	
K 7*	44	152	....	S. .07	00		33 680	11 000	.....	S. .37	11 000	S. .47	S. .17	9 600	.002	.01	
K 7:	44	152	....	S. .03	E. .02		33 680	28 000	.....	S. .08	8 000	S. .97	S. .46	> 7 000	.002	.02	
K 8*	48	166	....	00	E. .01		31 760	14 120	.....	N. ..	10 640	N. .44	N. .01	.....	....	....	Scale not disturbed.
Same shifted on bearings .01 south of axis.....							31 760	18 490	.....	N. .05	9 550	N. .69	N. .06	10 640	00	00	
K 9*	52	180	....	S. .05	E .04		36 000	15 000	.....	S. .11	8 300	S. .68	S .08				
Same, applying pressure at start to cause failure in opposite direction							.....	19 700	.....	N. .06	8 500	N. .82	N. .04	9 600			
Same, applying pressure at start to cause failure towards south again							.....	16 900	.....	S. .15	8 200	S .78	S. .09	.....	00	00	Scale not disturbed.
K. 9:	52	180	....	S. .06	W .05		36 000	12 000	.....	S. .12	9 100	S .46	S. .07				
Same shifted on bearings .06 north of axis.....							36 000	8 700	.....	N. .02	8 500	N. .30	S. .05				
" " .04 "							36 000	12 000	.....	S. .03	8 800	N. .35	S. .05				
" " .02 "							36 000	18 200	.....	S. .14	8 400	S. .89	S. .13	.....	00	00	Scale very slightly disturbed.
K 10*	56	194	....	N. .04	W. .08		34 180	8 000	... .	N .11	7 500	N. .47	N. .06	8 000	00	00	Scale not disturbed. Very slow.
K 10:	56	194	....	S. .01	E. .07		34 180	17 500	.....	S. .07	7 600	S. .86	S. .06	.....	....	....	Very sudden. Varying degrees of pressure at start gave maxima 17 000, 9 900, and 13 000, failures all toward south.
Same, applying pressure at start to cause failure in opposite direction							.....	13 900	.....	N. .09	7 500	N. .69	N. .01				
K 20*	60	208	....	S. .02	W .04		33 400	12 800	.....	N. .02	6 400	N. .68	N. 00	9 000	....	....	Rather sudden.
Same, applying pressure at start to cause failure in opposite direction							.....	14 900	.....	S. .13	6 700	S. .86	S. .05	15 000			
Same, applying pressure at start to cause failure towards north again							.....	18 000	.....	S. .04	5 400	N. .89	N. .06	.....	....	....	Started to fail towards west, veered north.

TABLE No. 10.

Detail of Tensile Test of 1-inch Square Steel, Series W.

Piece Mark..... W 5
Cross Section ..... 1.000 x 1.006.
Area ..... 1.006.
Gauged Length..... 8 and 10 inches.
Machine..... Emery 300 000.

Load applied. Pounds.	Stress per sq. in. Pounds.	Difference of extensions in units of .0001 inch.	Total extension Inches.	Extension per cent.	Set. Inches.	Remarks.
1 006	1,000	2.50	.000250	.0031		
5 030	5 000	9.50	.001200	.0150		
15 090	15 000	27.25	.003925	.0491	}	Modulus of extension = 29 630 000.
25 150	25 000	26.75	.006600	.0825		
35 210	35 000	27.00	.009300	.1162		
5 030	5 000	....	.001425	....	+.000225	Modulus of elasticity E = 30 420 000.
35 210	35 000	....	.009300	.1162		
40 240	40 000	13.75	.010675	.1334		
41 246	41 000	2.25	.010900	.1362		
42 252	42 000	2.50	.011150	.1394		
43 258	43 000	2.75	.011425	.1428		
44 264	44 000	2.50	.011675	.1459		
45 270	45 000	2.75	.011950	.1494		
46 276	46 000	2.50	.012200	.1525		
47 282	47 000	3.75	.012575	.1572	....	Bar scaling upper end outside of gauge points.
47 782	47 500	446.00	.057175	.7159	....	Scaling lower end, elastic limit by beam.
47 782	47 500	250.00	.082175	1.03	....	One minute later.
47 782	47 500	975.00	.179675	2.25	....	Two minutes later.
47 782	47 500	.00	.179675	2.25	....	One minute later.
47 782	47 500	10 00	.180675	2.26	....	"
47 782	47 500	7.00	.181375	2.27	....	"
48 288	48 000	8.00	.182175	2.28	....	"
49 294	49 000	12.00	.183375	2.28	....	"
50 300	50 000	240.00	.207375	2.59	....	"
51 306	51 000	109.00	.218275	2.73	....	"
52 312	52 000	229.00	.241175	3.01		
54 324	54 000	380.00	.279175	3.49		
56 336	56 000	495.00	.328675	4.11		
58 348	58 000	535.00	.382175	4.78		
60 360	60 000	640.00	.446175	5.58	....	Micrometer removed. Above on gauged length 8 in., below on 10 in.
62 372	62 000	....	0.70	7.0		
64 384	64 000	....	0.81	8.1		
66 396	66 000	....	0.98	9.8		
68 408	68 000	....	1.18	11.8		
70 420	70 000	....	1.67	16.7		
70 780	70 760	....	2.17	21.7	....	Maximum load. Extension taken as load begins to fall.
70 000	69 580	....	2.38	23 8		
67 000	66 600	....	2.51	25.1		
56 000	55 660	....			....	Breaking load.
			2.71	27.1	....	After rupture.

Appearance of fracture, fine, silky and dull. Radial markings.
Position of fracture, 3½ inches from end mark.
Diameter, .660 square.
Per cent. reduction, 56.7.
Elongation of inch sections, .23 × .28 × .69 (fracture) × .30 ×. 26 × .21 × .20 × .19 × .18 × .17.

TABLE No. 11.

Detail of Compression Test of 1-inch Square Steel, Series W.

Piece Mark ..... W 5
Cross Section ..... 1.005 x 1.002.
Area ..... 1.007.
Gauged Length = ...Total = 4.020 inches.
Machine ..... Emery 300 000.

Load applied. Pounds.	Stress per square inch original. Pounds.	Stress per square inch actual. Pounds.	Permanent compression. In.	Permanent compression per ct.	Enlarged Dimensions.	Enlarged area.	Remarks.
							Specimen removed for measurement after each load.
40 280	40 000	....	00	00	.....	..	Load held one minute.
45 315	45 000	....	00	00	.....	..	" "
46 322	46 000	....	.001	0.02	.....	..	" "
48 820	48 480	....	.0035	0.09	.....	..	Elastic limit shown by beam, released load immediately.
47 831	47 500	....	.006	0.15	.....	..	Load held one minute.
47 831	47 500	....	.035	0.87	.....	..	" "
47 831	47 500	....	.042	1.05	.....	..	" "
47 831	47 500	....	.050	1.25	.....	..	" "
47 831	47 500	....	.057	1.42	.....	..	" "
48 820	48 480	....	.079	1.97	.....	..	" "
48 820	48 480	....	.081	2.02	.....	..	" "
48 820	48 480	....	.082	2.05	.....	..	" "
50 350	50 000	....	.085	2.12	.....	..	" "
52 364	52 000	....	.099	2.47	.....	..	" "
54 378	54 000	....	.112	2.80	.....	..	" "
56 392	56 000	54 320	.125	3.12	1.018×1.020	1.038	" "
60 420	60 000	57 520	.155	3.87	1.026×1.024	1.050	" "
70 490	70 000	66 030	.238	5.95	1.032×1.035	1.067	" "
80 560	80 000	73 250	.343	8.57	1.047×1.050	1.099	" "
90 630	90 000	78 380	.482	12.05	1.075×1.075	1.155	" " Specimen skewed so much that it slips on face of platform. Test discontinued.

TABLE No. 12.

Detail of Tensile Test of 1-inch Square Iron, Series K.

Piece Mark ..... K 11
Cross Section ..... 1.005 square.
Area ..... 1.010.
Gauged Length ..... 8 and 10 inches.
Machine ..... Emery 300 000.

Load applied. Pounds.	Stress per square inch. Pounds.	Difference of extension in units of .0001 inch.	Total extension. Inches.	Extension per cent.	Set. Inches.	Remarks.
5 050	5 000	15.00	.001500	.0187		
10 100	10 000	14.00	.002900	.0362		
15 150	15 000	14.75	.004375	.0547	.....	$E = 27\,910\,000$
20 200	20 000	14.00	.005775	.0722		
5 050	.....	.....	.001475	....	—.000025	
25 250	25 000	14.00	.007175	.0897		
26 260	26 000	3.00	.007475	.0934		
27 270	27 000	3.00	.007775	.0972		
28 280	28 000	2.75	.008050	.1006		
29 290	29 000	4.00	.008450	.1056		
30 300	30 000	3.00	.008750	.1094		
31 310	31 000	6.00	.009350	.1169		
32 020	31 700	1 108.00	.120150	1.50	.....	Elastic limit by beam, held one minute.
32 320	32 000	11.00	.121250	1.52		
33 330	33 000	29.00	.124150	1.55		
34 340	34 000	380.00	.162150	2.03		
35 350	35 000	180.00	.180150	2.25		
36 360	36 000	300.00	.210150	2.63	.....	Micrometer removed. Above on gauged length of 8 inches, below on 10 inches.
38 380	38 000	.....	0.32	3.2		
40 400	40 000	.....	0.43	4.3		
42 420	42 000	.....	0 54	5.4		
44 440	44 000	.....	0.69	6.9		
46 460	46 000	.....	0.90	9.0		
48 480	48 000	.....	1.22	12.2		
50 300	49 800	.....	1.94	19.4	.....	Maximum load.
46 000	45 540	.....	.....	....	.....	Breaking load. Fell rapidly after maximum.
			2.13	21.3	.....	After rupture.

Appearance of fracture, 100 per cent. fibrous.
Position of fracture, $1\frac{1}{2}$ inches from end mark.
Diameter, .835 × .840.
Per cent. reduction, 30.5.
Elongation of inch sections, .30 × .37 (fracture) × .22 × .20 × .19 × .18 × .17 × .17 × .16 × .17.

SUMMARY OF TENSILE TEST OF 1-INCH SQUARE IRON.

Series K, Piece mark K 5.

Elastic limit..... = 32 280 pounds per square inch.
Ultimate strength..... ..... = 50 490 " "
Elongation in 10 inches..... = 25.2 per cent.
Reduction of area..... = 38.0 "
Fracture fibrous..... ..... 100 "

TABLE No. 13.

Detail of Compression Test of 1-inch Square Iron, Series K.

Piece Mark..... K 11
Cross Section..... .995 x .995.
Area..... .990.
Gauged Length = ...Total = 3.984.
Machine ..... Emery 300 000.

Load applied. Pounds.	Stress per square inch original. Pounds.	Stress per square inch actual. Pounds.	Permanent shortening. Inches.	Permanent shortening per cent.	Enlarged dimensions.	Enlarged area.	Remarks.
19 800	20 000	....	000	00	.....	..	Load held one minute.
24 750	25 000	....	000	00	.....	..	" "
25 740	26 000	....	000	00	.....	..	" "
26 730	27 000	....	000	00	.....	..	" "
27 720	28 000	....	000	00	.....	..	" "
28 710	29 000	....	000	00	.....	..	" "
29 700	30 000	....	.0005	0.01	.....	..	" "
30 690	31 000	....	.0015	0.04	.....	..	" "
31 680	32 000	....	.003	0.07	.....	..	" "
32 670	33 000	....	.022	0 55	.....	..	" "
32 670	33 000	....	.023	0.57	.....	..	" four minutes. Principal elastic limit.
33 660	34 000	33 830	.024	0.60	.998×.997	.995	Load held one minute.
34 650	35 000	....	.027	0.67	.....	..	" "
35 640	36 000	....	.030	0.75	.....	..	" "
36 630	37 000	....	.032	0.80	.....	..	" "
37 620	38 000	37 690	.039	0.97	.999×.999	.998	" "
38 610	39 000	....	.042	1.05	.....	..	" "
39 600	40 000	39 600	.046	1.15	1.000×1.000	1.000	" "
41 580	42 000	....	.052	1.30	.....	..	" "
43 960	44 400	43 710	.069	1.72	1.003×1.003	1.006	" "
45 540	46 000	45 190	.082	2.05	1 004×1.004	1.008	" "
47 520	48 000	46 890	.098	2.45	1.007×1.007	1.014	" "
49 500	50 000	48 440	.116	2.90	1.010×1.012	1.022	" "
54 450	55 000	52 340	.171	4.27	1.020×1.020	1.040	" "
59 400	60 000	56 240	.236	5.90	1.028×1.028	1.056	" "
64 350	65 000	59 500	.313	7.82	1.040×1.040	1.081	" "
69 300	70 000	62 250	.408	1.02	1.055×1.055	1.114	" "
80 700	81 620	....	.756	1.89	.....	..	Skewed $\frac{1}{16}$-inch. Test discontinued. Cross section out of square and irregular.

TABLE No. 14.

Detail of Compression Test of 1-inch Round Steel, as from Rolls.

Laboratory Number..... 2336a.
Piece Mark..... 2336a.
Cross Section..... 1.007.
Area..... .800.
Gauged Length..... 8 inches central.
Total Length..... 12.015.
Machine..... Emery.

Load applied. Pounds.	Stress per square inch. Pounds.	Difference of shortening in units of .0001 in.	Total shortening. Inches.	Shortening per cent.	Set.	Remarks.
1 600	2 000	6.25	.000625	.0078		
4 000	5 000	8.75	.001500	.0187		
8 000	10 000	14.50	.002950	.0369	.....	
12 000	15 000	14.50	.004400	.0550	.....	
16 000	20 000	13.75	.005775	.0722	.....	$E = 28\,830\,000$. Modulus of compression = 28 680 000.
20 000	25 000	14.00	.007175	.0897	.....	
24 000	30 000	13.75	.008550	.1069	.....	
28 000	35 000	13.25	.009875	.1234	.....	
4 000	5 000	....	.....	....	+.000050	
32 000	40 000	12.75	.011150	.1394		
32 800	41 000	2.75	.011425	.1428		
33 600	42 000	2.25	.011650	.1456		
34 400	43 000	2.50	.011900	.1487	.....	First break of scale, lower end.
35 200	44 000	2.25	.012125	.1516		
36 000	45 000	2.50	.012375	.1547		
36 800	46 000	2.25	.012600	.1575		
37 600	47 000	2.50	.012850	.1606		
38 400	48 000	3.00	.013150	.1644		
38 800	48 500	1.25	.013275	.1659	.....	Scaled 1¼ inches lower end.
39 200	49 000	3.25	.013600	.1700		
39 600	49 500	5.75	.014175	.1772	.....	Going.
39 600	49 500	17.50	.015925	.1991		
39 600	49 500	26.00	.018525	.2316	.....	About ¾ minute intervals.
39 600	49 500	29.00	.021425	.2678		
39 600	49 500	34.50	.024875	.3109		
39 600	49 500	65.00	.031375	.3922	.....	Scales in middle. Gone by beam. Bending left front.
37 300	46 625	....	.....	....	.....	Fell to this slowly.
38 000	47 500	....	.....	....	.....	Rose to this slowly.
00	00	....	.175	2.19	.....	Removed and measured.
						Replaced.
38 400	48 000	....	.....	....	.....	Second maximum.
28 000	35 000	....	.....	....	.....	Load falling. Removed.
						Upper bearing opened at edge.

Maximum ordinate 1 inch above middle = .61 inch.
Chord shortening..... = 0.315 "

APPENDIX.

CAMBRIA IRON COMPANY—TESTING LABORATORY.

JOHNSTOWN, PA., May, 1887.

DETAIL REPORTS OF COMPRESSION TESTS OF 1-INCH SQUARE STEEL, SERIES W. 70 000-POUND CAMBRIA BESSEMER STEEL, WITH HINGED ENDS.

EXPLANATIONS.

All tested as from rolls, not cold straightened.

Ends of bars were plane, and rested on hinged-rocker bearings with lubricated pins, the bearing surface of which is in plane of axes of pins.

Deviations were taken at middle of bar, and are referred to the straight line passing through centers of ends of bar. Deviations given for load 00 were measured before putting bar into testing machine by applying a straight edge. Deviations under load were obtained by measuring with a steel scale the ordinates from fine fish cords stretched parallel to bar by means of a clamp at bottom, to which one end of cord was fastened, and a similar clamp at top carrying grooved pulleys over which the cords passed with weights attached to overhanging ends. Deviations under no load and under initial load of 200 or 500 pounds are assumed to be equal.

The tests were made on a vertical 300 000-pound Emery Testing machine. Axis of pins in all cases east and west. All bars, except a few of the longest ones, were scribed every inch on all four sides, and the inches are referred to by numbers beginning at bottom.

Marked end of bar was down in all cases.

Description of Specimen.	Load. Lbs.	Load. Lbs. per sq. in.	Deviations. N.	S.	E.	W.	Remarks.
			In.	In.	In.	In.	
Mark, W 5	00	00	..	00	..	00	
	200	....	..	00	..	00	
Length, 12.03 in.	5 000	....	..	00	..	00	
	10 000	....	..	00	..	00	
Size,	20 000	....	..	.005	..	00	
1.000 x 1.005 in.	30 000	....	..	.005	..	00	
	40 000	....	..	.005	..	00	
	41 000	....	..	.005	..	00	
	42 000	....	..	.005	..	.005	
	43 000	....	..	.005	..	.005	
	44 000	....	..	.005	..	.005	
	45 000	....	..	.005	..	.005	
	46 000	....	..	.005	..	.005	
	47 000	....	..	.005	..	.005	
	48 000	....	..	.005	..	.005	
	49 000	....	..	.005	..	00	
	50 000	....	..	.005	..	00	
	51 000	....	..	.005	..	00	Scaling on ends, slightly at middle.
	51 600	51 350	..	.01	..	00	Gone.
	49 800	....	..	.01	..	00	Scaled 2 inches upper end, 1½ inches lower end.
	49 800	....	..	.01	.01	..	
	49 800	....	..	.01	.01	..	Scaled 3 inches upper end, 2 inches lower end.
	50 000	....	.02	..	.03	..	Scaled 4 inches upper end, 3 inches lower end.
	48 600	....	.03	..	.05	..	Scaled 5 inches upper end, 3 inches lower end.
	49 400	....	.03	..	.07	..	Scaled 6 inches upper end, 3 inches lower end.
	45 500	....	..	..	.22	..	
	45 000	....	.09	..	.28	..	
	200	....	.09	..	.27	..	
	5 000	....	.09	..	.27	..	
	10 000	....	.09	..	.27	..	
	15 000	....	.09	..	.27	..	
	20 000	....	.09	..	.28	..	
	25 000	....	.09	..	.28	..	
	30 000	....	.09	..	.28	..	
	35 000	....	.09	..	.28	..	
	36 000	....	.09	..	.28	..	
	37 000	....	.09	..	.29	..	
	38 000	....	.09	..	.29	..	
	39 000	....	.09	..	.29	..	
	40 000	....	.10	..	.29	..	
	41 000	....	.10	..	.29	..	
	42 000	....	.10	..	.29	..	
	43 000	....	.10	..	.29	..	
	44 000	....	.10	..	.29	..	
	44 800	....	.11	..	.30	..	
	43 200	....	.12	..	.32	..	Specimen removed.

Chord shortening = .33 inch.

	At	1	2	3	4	5	6	7	8	9	10	11 inches.
Ordinates west		.02	.04	.14	.22	.30	.32	.30	.24	.16	.09	.04 inch.
" south		.02	.05	.09	.12	.12	.13	.11	.09	.06	.04	.02 "

Shortening Per Inch.

	1	2	3	4	5	6	7	8	9	10	11	12 inches.
West Side	.02	.015	.015	.01	.03	.045	.05	.04	.03	.04	.02	.02 inch.
East Side	.04	.04	.03	.02	00	—.01	00	00	.02	.03	.05	.05 "

Description of Specimen.	Load. Lbs.	Load. Lbs. per sq. in.	Deviations. N.	S.	E.	W.	Remarks.
				In.		In.	
Mark, W 8	00	00	..	00	..	00	
	200	....	..	00	..	00	
Length, 12.04 in.	5 000	....	..	00	..	00	
	10 000	....	..	00	..	00	
Size,	20 000	....	..	00	..	00	
1.003 x 1.004 in.	30 000	....	..	00	..	00	
	40 000	....	..	00	..	00	
	41 000	....	..	00	..	00	
	42 000	....	..	00	..	00	
	43 000	....	..	00	..	00	
	44 000	....	..	00	..	00	
	45 000	....	..	00	..	.01	
	46 000	....	..	00	..	.01	
	47 000	....	..	00	..	.01	Scaled 2 inches at upper end.
	47 800	47 480	..	00	..	.02	Gone.
	47 800	....	..	00	..	.01	Scaled 2½ inches upper end, 1 inch lower end.
	48 000	....	..	.005	..	.01	
	48 800	48 470	..	.01	..	.02	Scaling more rapidly.
	48 000	....	..	.03	..	.02	Scaled 5 inches upper end, 1 inch lower end.
	46 000	....	..	.07	..	.03	
	40 000	....	..	.25	..	.03	Scaled 7 inches upper end, 1 inch lower end.
	35 000	....	..	.32	..	.04	
	33 000	....	..	.28	..	.04	Probably extent of rocking motion.
	34 300	....	..	.30	..	.04	
	36 000	....	..	.32	..	..	Past extent of rocking motion.
	200	....	..	.32	..	.04	
	5 000	....	..	.32	..	..	
	10 000	....	..	.33	..	..	
	15 000	....	..	.33	..	..	
	25 000	....	..	..	..	..	Extent of rocking motion. Specimen removed.

After Specimen Removed.

	At	1	2	3	4	5	6	7	8	9	10	11	12	inches.
Ordinates	North	.07	.14	.21	.29	.35	.38	.35	.32	.25	.16	.08	..	inch.
"	East	.02	.025	.03	.04	.04	.045	.04	.04	.03	.02	00	—.02	"

Shortening Per Inch.

At	1	2	3	4	5	6	7	8	9	10	11	12	inches.
North Side	.005	0	0	0	.02	.04	.04	.035	.025	.025	.025	.02	inch.
East Side	.01	0	0	0	0	0*	0*	0†	.01	.01	.04	.04	"

* Scale disturbed by tension. † Scale disturbed by compression.

Description of Specimen.	Load. Lbs.	Load. Lbs per sq. in.	Deviations. N.	S.	E.	W.	Remarks.
			In.			In.	
Mark, W 8:	00	C0	.02	..	..	.03	
	200	....	.02	..	..	.03	
Length, 32.00 in.	5 000	....	.02	..	..	.02	
	10 000	....	.02	..	..	.02	
Size,	15 000	....	.03	..	..	.02	
1.003 x 1.005 in.	20 000	....	.03	..	..	.02	
	25 000	....	.03	..	..	.02	
Twist to right = .02	30 000	....	.03	..	..	.02	
inch.	35 000	....	.04	..	..	.02	
	36 000	....	.04	..	..	.02	
	37 000	....	.04	..	..	.02	
	38 000	....	.04	..	..	.02	
	39 000	....	.04	..	..	.02	
	40 000	....	.04	..	..	.02	
	41 000	....	.05	..	..	.02	
	42 000	....	.05	..	..	.02	
	43 000	....	.05	..	..	.02	
	44 000	....	.055	..	..	.02	
	45 000	....	.06	..	..	.03	
	46 000	45 650	.08	..	..	.03	Goes very suddenly.
	15 900	....	.98	..	..	..	
	200	....	.60	..	..	.01	
	5 000	....	.70	..	..	.01	
	6 000	....	.74	..	..	.01	
	7 000	....	.76	..	..	.01	
	8 000	....	.81	..	..	.02	
	9 000	....	.84	..	..	.02	Extent of motion. Specimen removed.

Ordinate south at middle = .62 inch.
East and west practically straight.
Chord shortening..... = .04 inch.

Shortening Per Inch.

South Side	1 to 13	14	15	16	17	18	19	20 to 32	
	0	.01	.01	.02	.02	.01	.005	0	
North Side	1	2 to 14	15	16	17	18 to 32			
	.005	0	—.005	—.01	—.01	0			

Description of Specimen.	Load. Lbs.	Load. Lbs. per sq. in.	Deviations. N.	S.	E.	W.	Remarks.
			In.			In.	
Mark, W 6:	00	00	.03	..	..	.02	
	200	....	.03	..	..	.02	
Length, 34.04 in.	5 000	....	.04	..	..	.02	
	10 000	....	.04	..	..	.02	
Size,	15 000	....	.05	..	..	.02	
1.006 x 1.003 in.	20 000	....	.05	..	..	.02	
	25 000	....	.05	..	..	.02	
	30 000	....	.06	..	..	.01	
	31 000	....	.06	..	..	.01	
	32 000	....	.06	..	..	.01	
	33 000	....	.07	..	..	.01	
	34 000	....	.07	..	..	.02	
	35 000	....	.07	..	..	.02	
	36 000	....	.07	..	..	.02	
	37 000	....	.07	..	..	.02	
	38 000	....	.07	..	..	.02	
	39 000	....	.08	..	..	.02	
	40 000	....	.08	..	..	.02	
	41 000	....	.08	..	..	.02	
	42 000	....	.09	..	..	.02	
	43 000	....	.09	..	..	.02	
	44 000	....	.10	..	..	.02	
	45 000	44 620	..	..	..	..	Failed.
	15 800	....	.89	..	..	..	
	14 000	....	.97	..	..	..	
	200	....	.64	..	..	.02	
	5 000	....	.76	..	..	..	
	6 000	....	.79	..	..	..	
	7 000	....	.83	..	..	..	
	8 000	....	.87	..	..	..	Extent of motion. Specimen removed.

Ordinate south at middle = .65 inch.
East and west practically straight.
Chord shortening..... = .04 inch.

Shortening Per Inch.

South Side	1 to 14	15	16	17	18	19	20	21 to 34	
	0	.005	.005	.015	.015	.01	.005	0	
North Side	1 to 16	17	18	19	20 to 34				
	0	—.005	—.005	—.005	0				

Description of Specimen.	Load. Lbs.	Load. Lbs. per sq. in.	Deviations. N.	S.	E.	W.	Remarks.
			In.		In.		
Mark, W 8:	00	....	.06	..	.03	..	
	200	....	.05	..	.03	..	
Length, 35.97 in.	5 000	....	.07	..	.03	..	
	10 000	....	.08	..	.04	..	
Size,	15 000	....	.085	..	.03	..	
1.007 x 1.003 in.	20 000	....	.095	..	.03	..	
	25 000	....	.11	..	.03	..	
Ends square.	26 000	....	.11	..	.03	..	
	27 000	....	.12	..	.03	..	
Twist to right.	28 000	....	.125	..	.03	..	
	29 000	....	.125	..	.03	..	
	30 000	....	.13	..	.03	..	
	31 000	....	.135	..	.035	..	
	32 000	31 680	.15	..	.04	..	Failed.
	15 000	....	.74	..	..	..	
	200	....	.28	..	.04	..	
	1 000	....	.28	..	..	..	
	2 000	....	.29	..	..	..	
	3 000	....	.30	..	..	..	
	4 000	....	.31	..	..	..	
	5 000	....	.33	..	..	..	
	6 000	....	.34	..	..	..	
	7 000	....	.36	..	..	..	
	8 000	....	.38	..	..	..	
	9 000	....	.40	..	..	..	
	10 000	....	.43	..	..	..	
	11 000	....	.45	..	..	..	
	12 000	....	.51	..	..	..	
	13 000	....	.57	..	..	..	
	14 000	....	.65	..	..	..	
	14 500	....	.70	..	.04	..	Extent of motion. Specimen removed.

Ordinate south at middle = .28 inch.
Chord shortening..... = .01 "

Shortening Per Inch.

South Side	1 to 12	13	14	15	16	17	18	19	20	21	22	23 to 36
	0	.005	.005	.005	.005	.005	.005	.005	.005	.005	.005	0

North Side.—Scale very slightly disturbed in 18 and 19 inches.

Description of Specimen.	Load. Lbs.	Load. Lbs. per sq. in.	Deviations. N.	S.	E.	W.	Remarks.
			In.	In.		In.	
Mark, W 7.	00	00	..	.01	..	.03	
	200	....	..	.01	..	.03	
Length, 37.97 in.	5 000	....	..	.01	..	.02	
	10 000	....	..	0	..	.02	
Size,	15 000	....	..	0	..	.01	
1.000 x 1.003 in.	20 000	....	..	0	..	.02	
	25 000	....	.01	..	..	.02	
Ends square.	30 000	....	.02	..	..	.02	
	31 000	....	.02	..	..	.02	
	32 000	....	.025	..	..	.02	
	33 000	....	.025	..	..	.02	
	34 000	....	.03	..	..	.02	
	35 000	....	.03	..	..	.02	
	36 000	....	.03	..	..	.02	
	37 000	....	.04	..	..	.02	
	38 000	....	.04	..	..	.02	
	39 000	....	.05	..	..	.02	
	40 000	....	.06	..	..	.02	
	41 000	....	.07	..	..	.03	
	41 800	41 690	.11	..	..	..	Going.
	13 600	....	> .90	..	..	..	Specimen is bent so much it throws cord out of line, and is past rocking motion.
	7 300	....	.80	..	..	..	Extent of rocking motion.
	200	....	.43	..	..	.01	
	1 000	....	.44	..	..	..	
	2 000	....	.46	..	..	..	
	3 000	....	.49	..	..	..	
	4 000	....	.52	..	..	..	
	5 000	....	.55	..	..	..	
	6 000	....	.58	..	..	..	
	7 000	....	.63	..	..	..	
	8 000	....	.68	..	..	..	
	9 000	....	.74	..	..	..	
	10 000	....	.83	..	..	..	Extent of rocking motion. Specimen removed.

Ordinate south at middle = .48 inch.
Chord shortening..... = .02 "

Shortening Per Inch.

South Side	1 to 14	15	16	17	18	19	20	21	22	23	24	25 to 38
	0	.005	.005	.005	.005	.01	.01	.01	.01	.005	.005	0

North Side—Scale very slightly disturbed in middle three inches.

Description of Specimen.	Load. Lbs.	Load. Lbs per sq. in.	Deviations. N.	S.	E.	W.	Remarks.
				In.		In.	
Mark, W 8·	00	00	..	.015	..	.03	
	200	....	..	.015	..	.03	
Length, 39.96 in.	5 000	....	..	.015	..	.01	
	10 000	....	..	.015	..	.01	
Size,	15 000	....	..	.015	..	.01	
1.000 x 1 000.	20 000	....	..	.015	..	.01	
	25 000	....	..	.025	..	.01	
	30 000	....	..	.025	..	00	
	35 000	....	..	.035	..	00	
	36 000	....	..	.045	..	00	
	37 000	....	..	.045	..	00	
	37 980	37 980	..	..	..	..	Failed very suddenly.
	13 000	13 000	..	.975	..	..	Scale disturbed in middle 12 inches concave side, slightly on other side.
	200	....	..	.435	..	..	
	1 000	....	..	.445	..	..	
	2 000	....	..	.465	..	..	
	3 000	....	..	.505	..	..	
	3 500	....	..	.515	..	..	
	4 000	....	..	.545	..	..	
	4 500	....	..	.555	..	..	
	5 000	....	..	.585	..	..	
	5 500	....	..	.605	..	..	
	6 000	....	..	.635	..	..	
	7 000	....	..	.705	..	..	
	7 500	....	..	.725	..	..	
	8 000	....	..	.765	..	..	
	8 500	....	..	.805	..	..	
	9 000	....	..	.845	..	..	Extent of rocking motion.
	200	....	..	.435	..	..	Removed specimen.

Ordinate north at middle = .44 inch.
" west " = .015 "
Chord shortening..... = .01 "

Shortening Per Inch.

	1 to 18	19	20	21	22	23 to 40
North Side	0	.005	.005	.005	.005	0

South side not perceptible.

Description of Specimen.	Load. Lbs.	Load. Lbs. per sq. in.	Deviations. N.	S.	E.	W.	Remarks.
			In.		In.		
Mark, W 5·	00	00	.08	..	.015	..	
	200	....	.08	..	.015	..	
Length, 39.98 in.	3 000	....	.09	..	.015	..	
	5 000	....	.09	..	.015	..	
Size,	7 500	....	.10	..	.015	..	
1.000 x 1.005.	10 000	....	.11	..	.015	..	
	12 500	....	.12	..	.015	..	
Ends square.	15 000	....	.13	..	.015	..	
	17 500	....	.15	..	.015	..	
	19 300	19 210	..	..	..	..	Going. Failed.
	15 900	....	.59	..	.025	..	
	200	....	.12	..	.015	..	
	3 000	....	.13	..	..	..	
	5 000	....	.14	..	..	..	
	7 500	....	.16	..	..	..	
	10 000	....	.18	..	..	..	
	12 500	....	.21	..	..	..	
	14 900	....	.32	..	..	..	Going.
	15 000	....	.38	..	..	..	
	15 400	....	.48	..	..	..	
	15 400	....	.60	..	..	..	Scales on inside.
	200	....	.15	..	.025	..	Specimen removed.

Ordinate south at middle = .16 inch.
Chord shortening..... = 00 "

Shortening per inch not perceptible. Scale disturbed on middle 12 inches south side.

Description of Specimen.	Load. Lbs.	Load. Lbs. per sq. in.	Deviations. N.	S.	E.	W.	Remarks.
				In.		In.	
Mark, W 7·	00	00	00	00	..	.01	
	200	....	00	00	..	.01	
Length, 41.97 in.	5 000	....	..	.01	..	.01	
	10 000	....	..	.01	..	.01	
Size,	15 000	....	..	.01	..	00	
1.000 x 1.000.	20 000	....	..	.01	..	.01	
	25 000	....	..	.02	..	.01	
Twist right	30 000	....	..	.02	..	.01	
hand = .06 in.	31 000	....	..	.02	..	.01	
	32 000	....	..	.03	..	.01	
	33 000	....	..	.03	..	.01	
	34 000	34 000	..	..	..	..	Failed very suddenly.
	13 600	....	..	.85	..	..	Extent of rocking motion.
	200	....	..	.23	..	.01	Scale disturbed middle 14 inches north side.
	1 000	....	..	.24	..	..	
	2 000	....	..	.25	..	..	
	3 000	....	..	.27	..	..	
	4 000	....	..	.29	..	..	
	5 000	....	..	.31	..	..	
	6 000	....	..	.34	..	..	
	7 000	....	..	.38	..	..	
	8 000	....	..	.43	..	..	
	9 000	....	..	.50	..	..	
	10 000	....	..	.60	..	..	
	11 000	....	..	.73	..	..	
	11 800	....	..	.82	..	..	Extent of rocking motion.
	200	....	..	.23	..	..	Removed specimen.

Ordinate north at middle = .25 inch.
" East " = .01 "
Chord shortening..... = 0 "

Shortening Per Inch.

North Side { Middle 6 inches total. .025 — Middle 2 inches total. .01

South Side not perceptible.

Description of Specimen.	Load. Lbs.	Load Lbs. per sq. in.	Deviations. N.	S.	E.	W.	Remarks.
			In.		In.		
	00	00	.05	..	..	00	
Mark, W 7:	200	....	.05	..	..	00	
	5 000	....	.04	..	..	00	
Length, 41.97 in.	10 000	....	.06	..	.01	..	
	15 000	....	.09	..	.01	..	
Size,	16 000	....	.10	..	.01	..	
1.000 x 1.000.	16 600	16 600	..	..	..	..	Failed slowly.
	14 600	....	.39	..	..	..	
	14 500	....	.40	..	..	..	
	14 500	....	.42	..	..	..	
	200	....	.05	..	00	..	Scale undisturbed.
	5 000	....	.06	..	00	..	
	10 000	....	.07	..	00	..	
	12 000	....	.09	..	.01	..	
	13 000	....	.10	..	.01	..	
	14 000	....	.10	..	.01	..	
	15 000	....	.12	..	.01	..	
	15 800	....	..	..	..	..	Failed.
	14 700	....	.35	..	..	..	
	14 900	....	.54	..	..	..	
	14 500	....	.62	..	..	..	
	14 000	....	.69	..	..	..	Scale disturbed slightly in middle 12 inches south side.
	13 500	....	.73	..	..	..	
	200	....	.14	..	..	..	Removed specimen.

Ordinate north at middle = .14 inch.
" west " = .02 "
Chord shortening..... = 00 "
Shortening per inch not perceptible where scale disturbed.

Description of Specimen.	Load. Lbs.	Load. Lbs. per sq. in.	Deviations. N.	S.	E.	W.	Remarks.
			In.			In.	
	00	00	.06	..	..	.02	
Mark, W 7·	200	....	.06	..	..	.02	
	5 000	....	.06	..	..	.02	
Length, 43.97 in.	10 000	....	.06	..	..	.01	
	12 000	....	.07	..	..	.01	
Size,	13 000	....	.07	..	..	.01	
1.000 x 1.000 in.	14 000	....	.07	..	..	.01	
	15 000	....	.07	..	..	.01	
Has some dents on	16 000	....	.08	..	..	.01	
the corners, and	17 000	....	.08	..	..	.02	
right hand twist	18 000	....	.08	..	..	.02	
= .06 in.	19 000	....	.08	..	..	.02	
	20 000	....	.08	..	..	.02	
	200	....	.06	..	..	..	To confirm original deviation.
	20 000	....	.08	..	..	.02	
	21 000	....	.09	..	..	.01	
	22 000	....	.09	..	..	.01	
	23 000	....	.10	..	..	.01	
	24 000	....	.10	..	..	.01	
	25 000	....	.11	..	..	.01	
	26 000	26 000	.12	..	..	..	Failed.
	12 100	12 100	.82	..	..	.01	Not quite extent of rocking motion. Scale slightly disturbed in middle 12 inches south side.
	200	....	.16	..	..	.01	
	1 000	....	.16	..	..	..	
	2 000	....	.16	..	..	..	
	3 000	....	.17	..	..	..	
	4 000	....	.18	..	..	..	
	5 000	....	.19	..	..	..	
	6 000	....	.20	..	..	..	
	7 000	....	.21	..	..	..	
	8 000	....	.22	..	..	..	
	9 000	....	.25	..	..	..	
	10 000	....	.28	..	..	..	
	11 000	....	.35	..	..	..	
	12 000	....	.51	..	..	..	Going.
	12 000	....	.56	..	..	..	
	12 400	....	.66	..	..	..	
	12 700	....	.96	..	..	..	Scale disturbed in middle.
	200	....	.24	..	..	.01	Specimen removed.

Ordinate south at middle = .20 inch.
" west " = .01 "
Chord shortening..... = 00 "

Shortening apparently .01 inch in middle six inches, south side.

Description of Specimen.	Load. Lbs.	Load. Lbs. per sq. in.	Deviations. N.	S.	E.	W.	Remarks.
				In.	In.		
Mark, W 7:	00	00	..	.025	.01	..	
	200	....	..	.025	.01	..	
Length, 43.97 in	5 000	....	..	.02	.01	..	
	10 000	....	..	.02	.01	..	
Size,	15 000	....	..	.03	.01	..	
1.000 x 1.000 in	20 000	....	..	.03	.01	..	
	25 000	....	..	.04	.01	..	
No twist.	26 000	....	..	.04	.01	..	
	27 000	....	..	.05	.01	..	
	28 000	....	..	.05	01	..	
	29 000	....	..	.05	.01	..	
	3 · 000	30 000	..	.06	..	..	Failed very suddenly.
	12 200	12 200	..	.87	..	..	Scale disturbed in middle 15 inches north side.
	200	....	..	.16	00	..	
	1 000	....	..	.16	..	..	
	2 000	....	..	.18	..	..	
	3 000	....	..	.19	..	..	
	4 000	....	..	.20	..	..	
	5 000	....	..	.21	..	..	
	6 000	....	..	.23	..	..	
	7 000	....	..	.25	..	..	
	8 000	....	..	.30	..	..	
	9 000	....	..	.36	..	..	
	10 000	....	..	.45	..	..	
	11 000	....	..	.63	..	..	
	12 000	....	..	.85	..	..	Extent of rocking motion.
	200	..	..	.17	..	..	Specimen removed.

Ordinate north at middle, = .18 inch.
" east " = .01 "
Chord shortening..... = 00 "
Shortening per inch not perceptible.

Description of Specimen.	Load. Lbs.	Load. Lbs. per sq. in.	Deviations. N.	S.	E.	W.	Remarks.
			In.		In.		
Mark, W 6:	00	00	.06	..	.04	..	
	200	....	.06	..	.04	..	
Length, 48.00 in.	5 000	....	.09	..	.04	..	
	6 000	....	.11	..	.03	..	
Size,	7 000	....	.11	..	.03	..	
1.003 x 1.003 in.	8 000	....	.13	..	..	..	
	8 000	....	.14	..	.03	..	
Right hand twist =	9 000	....	.20	..	.03	..	
.05 in.	10 000	....	.34	..	.04	..	
	10 600	....	.72	..	..	..	
	10 720	10 660	.92	..	..	..	Failed.
	200	....	.15	..	.03	..	
	1 000	....	.15	..	..	..	
	2 000	....	.17	..	..	..	
	3 000	....	.18	..	.	..	
	4 000	....	.20	..	..	..	
	5 000	....	.22	..	..	..	
	6 000	....	.27	..	..	..	
	7 000	....	.33	..	..	..	
	8 000	....	.42	..	..	..	
	9 000	....	.62	..	..	..	
	9 900	9 850	.92	..	..	..	Extent of rocking motion. Scale slightly disturbed in middle 14 inches south side, but shortening per inch not perceptible.

Ordinate south at middle = .16 inch
" west " = .04 "
Chord shortening..... = .005 "

Description of Specimen.	Load. Lbs.	Load. Lbs. per sq. in.	Deviations.				Remarks.
			N.	S.	E.	W.	
			In.			In.	
Mark, W 6·	00	00	.02	..	..	.03	
	200	....	.02	..	..	.03	
Length, 48.00 in.	5 000	....	.03	..	..	.02	
	10 000	....	.04	..	..	.02	
Size,	13 200	13 130	.40	..	..	..	Failed.
1.003 x 1.003 in.	11 600	11 540	.52	..	..	..	
	200	....	.02	..	..	.03	
	5 000	....	.02	..	..	.02	
	10 000	....	.03	..	..	.03	
	11 000	....	.04	..	..	.03	
	12 000	....	.04	..	..	.03	
	13 000	....	.05	..	..	.02	
	14 000	13 980	.06	..	..	..	Failed rather slowly.
	11 500	....	.45	..	..	..	
	200	....	.02	..	..	.03	
	00	....	.02	..	..	.03	Specimen placed .02 inch south of axis.
	200	....	.02	..	..	.03	
	5 000	....	.02	..	..	.02	
	10 000	....	.03	..	..	.03	
	11 000	....	.03	..	..	.03	
	12 000	....	.04	..	..	.03	
	13 000	....	.04	..	..	.03	
	14 000	....	.04	..	..	.03	
	15 000	....	.04	..	..	.03	
	16 000	....	.04	..	..	.03	
	17 000	....	.05	..	..	.03	
	18 000	....	.05	..	..	.04	
	19 000	....	.06	..	..	.04	
	20 000	....	.06	..	..	.04	
	21 000	....	.06	..	..	.04	
	22 000	....	.07	..	..	.04	
	23 000	22 870	.08	..	..	..	Failed suddenly. Scale slightly disturbed in middle 6 inches south side.
	11 500	11 440	.77	..	..	..	
	200	....	.04	..	..	.03	
	1 000	....	.04	..	..	.03	
	2 000	....	.04	..	..	.02	
	3 000	....	.04	..	..	.02	
	4 000	....	.05	..	..	.02	
	5 000	....	.05	..	..	.02	
	6 000	....	.05	..	..	.02	
	7 000	....	.05	..	..	.02	
	8 000	....	.06	..	..	.02	
	9 000	....	.06	..	..	.02	
	10 000	....	.07	..	..	.03	
	11 000	....	.07	..	..	.03	
	12 000	....	.07	..	..	.03	
	13 000	....	.08	..	..	.03	
	14 000	....	.08	..	..	.02	
	15 000	....	.09	..	..	.03	
	16 000	....	.10	..	..	.03	
	16 900	16 810	..	..	..	..	Failed.
	11 200	....	.57	..	..	..	
	200	....	.04	..	..	.03	Specimen removed.

Ordinate south at middle = .04 inch.
" east " = .03 "
Chord shortening..... = 00 "

Scale disturbed very slightly in middle 6 inches south side.

Description of Specimen.	Load. Lbs.	Load. Lbs. per sq. in.	Deviations.				Remarks.
			N.	S.	E.	W.	
			In.			In.	
Mark, W 9·	00	00	.04	..	..	.02	
	200	....	.04	..	..	.02	
Length, 51.96 in.	5 000	....	.06	..	..	.03	
	6 000	....	.07	..	..	.03	
Size,	7 000	....	.08	..	..	.03	
1.008 x 1.002 in.	8 000	....	.09	..	..	.03	
	9 000	....	.11	..	..	.03	
	9 900	9 810	.	..	..	..	Failed.
	9 500	....	..	..	..	..	
	9 300	9 210	.42	..	..	..	
	9 600	....	..	..	..	..	
	9 400	....	.54	..	..	..	
	9 600	....	.62	..	..	..	
	9 500	....	.72	..	..	..	
	200	....	.04	..	..	.02	
	500	....	..	..	..	..	Specimen placed .02 inch south of axis.
	200	....	.05	..	..	.02	
	5 000	....	.07	..	..	.03	
	6 000	....	.07	..	..	.03	
	7 000	....	.07	..	..	.03	
	8 000	....	.08	..	..	.03	
	9 000	....	.09	..	..	.04	
	10 000	....	.09	..	..	.04	
	11 000	....	.10	..	..	.04	
	12 000	....	.11	..	..	.04	
	13 000	....	.13	..	..	.04	
	13 400	13 270	..	..	..	..	Failed.
	9 900	....	.54	..	..	..	Scale not disturbed.
	200	....	.05	..	..	.02	
	500	....	..	..	..	..	Specimen placed .04 inch south of axis.
	200	....	.05	..	.	.02	
	5 000	....	.06	..	..	.03	
	6 000	....	.06	..	..	.03	
	7 000	....	.06	..	..	.03	
	8 000	....	.065	..	..	.04	
	9 000	....	.07	..	..	.04	
	10 000	....	.07	..	..	.04	
	11 000	....	.08	..	..	.04	
	12 000	....	.08	..	..	.04	
	13 000	....	.09	..	..	.04	
	14 000	....	.09	..	..	.04	
	15 000	....	.09	..	..	.04	
	16 000	....	.10	..	..	.05	
	17 000	....	.11	..	..	.05	
	18 000	....	.13	..	..	.06	
	19 000	18 810	.14	..	..	..	Failed.
	9 900	....	.79	..	..	..	Scale not disturbed.
	200	....	.05	..	..	.02	
	500	....	..	..	..	..	Specimen placed .06 inch south of axis.
	200	....	.05	..	..	.02	
	1 000	....	.05	..	..	.03	
	5 000	....	.05	..	..	.03	
	6 000	....	.05	..	..	.03	
	7 000	....	.05	..	..	.03	
	8 000	....	.05	..	..	.04	
	9 000	....	.05	..	..	.04	
	10 000	....	.05	..	..	.04	
	11 000	....	.05	..	..	.04	
	12 000	....	.05	..	..	.04	
	13 000	....	.05	..	..	.04	
	14 000	....	.05	..	..	.04	
	15 000	....	.05	..	..	.04	
	16 000	....	.05	..	..	.05	

(*Mark W 9· continued.*)

Description of Specimen.	Load. Lbs.	Load. Lbs per sq. in	Deviations.				Remarks.
			N.	S.	E.	W.	
			In.			In	
Mark, W 9·	17 000	....	.05	..	..	.05	
	18 000	....	.05	..	..	.05	
Length, 51.96 in.	19 000	....	.05	..	..	.06	
	20 000	....	.04	..	..	.06	
Size,	20 800	20 600	..	..	..	..	Failed.
1.008 x 1.002 in.	9 800	....	.72	..	..	..	
	200	....	.04	..	..	.02	
	5 000	....	.04	..	..	.03	
	10 000	....	.03	..	..	.04	
	11 000	....	.03	..	..	.04	
	12 000	....	.02	..	..	.04	
	13 000	....	.01	..	..	.04	
	14 000	13 870	..	..	..	..	Failed.
	9 706	....	.41	..	..	..	
	200	....	.04	..	..	.02	Specimen removed.

Ordinate south at middle.. = .04 inch.
" east · " .. = .02 "
Chord shortening..... = 0 "

Scale undisturbed.

Description of Specimen.	Load. Lbs.	Load. Lbs. per sq. in.	Deviations. N.	S.	E.	W.	Remarks.
			In.	In.	In.		
Mark, W 9:	00	00	00	..	.02	..	
	500	....	00	..	.02	..	
Length, 51.97 in.	5 000	....	.01	..	.02	..	
	10 000	....	.05	..	.02	..	
Size,	11 000	....	.06	..	.02	..	
1.005 x 1.002 in.	12 000	....	.07	..	.02	..	
	12 500	12 420	..	..	..	..	Failed.
	9 900	9 830	.42	..	.02	..	
	500	....	.01	..	.02	..	
	200	....	00	..	.02	..	
	5 000	....	..	.03	.02	..	By pressure on rockers in direction to correct deviation while load rises to 5 000.
	10 000	....	..	.02	.02	..	
	11 000	....	..	.02	.02	..	
	12 000	....	..	.02	.01	..	
	13 000	....	..	.02	.02	..	
	14 000	....	..	.02	.01	..	
	15 000	....	..	.02	.01	..	
	16 000	....	..	.02	.01	..	
	17 000	....	..	.02	.01	..	
	18 000	....	..	.02	.01	..	
	19 000	....	..	.02	.01	..	
	20 000	....	..	.02	.01	..	
	21 000	....	..	.02	.01	..	
	22 000	....	..	.02	.01	..	
	23 000	....	..	.02	.01	..	
	24 000	....	..	.03	.01	..	
	25 000	....	..	.03	.01	..	
	26 000	....	..	.03	.01	..	
	27 000	....	..	.03	.01	..	
	28 000	....	..	.04	.01	..	
	29 000	....	..	05	.01	..	
	30 000	29 810	..	.08	..	..	Failed. Extent of motion. Scale slightly disturbed in middle 14 in. north side.
	10 900	10 830	..	..	..	..	
	10 800	....	..	1.06	..	..	
	200	....	..	.09	.02	..	Applying pressure on rockers here produces no change; piece springs back.
	1 000	....	..	.10	.01	..	
	2 000	....	..	.10	.01	..	
	3 000	....	..	.11	.01	..	
	4 000	....	..	.12	.01	..	
	5 000	....	..	.13	.01	..	
	6 000	....	..	.14	.01	..	
	7 000	....	..	.15	.01	..	
	8 000	....	..	.16	.01	..	
	9 000	....	..	.21	..	..	Going.
	9 000	....	..	.23	..	..	
	9 800	9 730	..	.39	..	..	Going rapidly. Failed.
	9 300	....	..	.47	..	..	
	9 130	....	..	.47	..	..	
	9 500	....	..	.60	..	..	
	9 400	....	..	.79	..	..	
	200	....	..	.09	.02	..	Specimen removed.

Ordinate north at middle..... = .10 inch.
" west " .... = .03 "
Chord shortening .... = 00 "
Shortening on nort hside in middle 6 inches.. = .01 "
" " " 12 " = .01 "

Description of Specimen	Load. Lbs.	Load. Lbs. per sq. in.	Deviations. N.	S.	E.	W.	Remarks.
			In.	In.	In.		
Mark, W 6·	00	00	..	.09	.03	..	
	500	....	..	.09	.03	..	
Length, 55.93 in.	5 000	....	..	.12	.01	..	
	6 000	....	..	.14	.01	..	
Size,	7 000	....	..	.16	.01	..	
1.000 x 1.000 in.	8 000	....	..	.31	..	..	Going.
	8 000	....	..	.38	..	..	
Ordinate west	8 000	....	..	.38	..	..	Later.
at 20 in. = .04 in.	8 400	8 400	..	.54	..	..	Failed.
	8 000	8 000	..	.56	..	..	
	8 300	....	..	..	..	..	
	8 100	....	..	.72	..	..	
	500	....	..	.11	..	..	
	500	....	..	.08	.01	..	Specimen placed .09 inch north of axis.
	5 000	....	..	.07	.01	..	
	6 000	....	..	.07	.01	..	
	7 000	....	..	.06	.01	..	
	8 000	....	..	.03	.01	..	
	8 800	8 800	..	..	..	..	Failed.
	8 200	....	.21	..	..	..	
	500	....	..	.08	.02	..	
	500	....	..	.08	.01	..	Specimen placed .06 inch north of axis.
	5 000	....	..	.08	.01	..	
	6 000	....	..	.08	.01	..	
	7 000	....	..	.08	.01	..	
	8 000	....	..	.08	.01	..	
	9 000	....	..	.09	.01	..	
	10 000	....	..	.10	.01	..	
	11 000	....	..	.10	.01	..	
	12 000	....	..	.11	.01	..	
	13 000	....	..	.11	.01	..	
	14 000	....	..	.12	.01	..	
	15 000	....	..	.13	.01	..	
	16 000	....	..	.14	.01	..	
	17 000	....	..	.15	.01	..	
	18 000	....	..	.16	.01	..	
	18 900	18 900	..	.	..	..	Failed.
	8 700	8 700	..	.94	..	..	Rocker free.
	8 500	....	..	.93	..	..	
	500	....	..	.09	.01	..	
	500	....	..	.09	.01	..	Specimen placed .07 inch north of axis.
	5 000	...	..	.09	.01	..	
	10 000	....	..	.10	.01	..	
	11 000	....	..	.11	.01	..	
	12 000	....	..	.11	.01	..	
	13 000	....	..	.11	.01	..	
	14 000	....	..	.12	.01	..	
	15 000	....	..	.13	.01	..	
	16 000	....	..	.13	.01	..	
	17 000	....	..	.15	.01	..	
	18 000	....	..	.16	.01	..	
	19 000	....	..	.18	.01	..	
	20 000	20 000	..	.22	..	..	Failed suddenly. Rocker free.
	8 800	8 800	..	.99	..	..	
	7 700	....	..	.79	..	..	
	7 200	....	..	.59	..	..	
	6 800	....	..	.39	..	..	
	6 400	....	..	.29	..	..	
	5 900	....	..	.24	..	..	
	5 000	....	..	.18	..	..	
	4 000	....	..	.15	..	..	
	3 000	....	..	.14	..	..	
	2 000	....	..	.11	..	..	
	1 000	....	..	.10	..	..	
	500	....	..	.09	.01	..	Specimen removed.

After Removing Specimen.

Ordinate north at middle = .09 inch.
" west " = .02 "
Chord shortening..... = 00 "
Scale nowhere disturbed.

Description of Specimen.	Load. Lbs.	Load. Lbs. per sq. in.	Deviations.				Remarks.
			N.	S.	E.	W.	
			In.	In.	In.		
Mark, W 4.	00	00	..	.06	.04	..	
	500	....	..	.06	.03	..	
Length, 60.01 in.	1 000	....	..	.06	.03	..	
	5 000	....	..	.08	.01	..	
Size,	8 000	8 000	..	..	..	..	Failed.
1.000 x 1.000.	5 000	5 000	..	..	..	..	
	500	....	..	.06	..	..	
	5 000	....	..	.10	..	..	
	6 000	....	..	.10	.02	..	
	7 000	....	..	.13	.02	..	
	8 000	8 000	..	..	..	..	Failed.
	7 200	7 200	..	.41	..	..	
	500	....	..	.17	.03	..	
	500	....	..	.05	..	..	Applying pressure to rocker to bend bar and then removing pressure.
	500	....	..	.05	.03	..	Specimen placed .06 inch north of axis.
	5 000	....	..	.04	.02	..	
	6 000	....	..	.04	.01	..	
	7 000	....	..	.03	.01	..	
	8 000	....	..	.03	.01	..	
	9 000	....	..	.02	.02	..	
	10 000	10 000	..	..	..	..	Failed.
	7 300	7 300	.47	..	.01	..	
	500	....	..	.04	.03	..	
	500	....	..	.05	..	..	Applying pressure to rocker to bend bar and then removing pressure.
	500	....	..	.05	.04	..	Specimen placed .04 inch north of axis.
	5 000	....	..	.05	.02	..	
	6 000	....	..	.05	.02	..	
	7 000	....	..	.05	.02	..	
	8 000	....	..	.05	.02	..	
	9 000	....	..	.05	.02	..	
	10 000	....	..	.05	.02	..	
	11 000	....	..	.06	.02	..	
	12 000	....	..	.06	.02	..	
	13 000	....	..	.07	.02	..	
	14 000	....	..	.07	.02	..	
	15 000	....	..	.08	.02	..	
	16 000	....	..	.10	.02	..	
	17 000	....	..	.11	.02	..	
	17 900	17 900	..	..	..	..	Failed suddenly. Rocker free.
	7 300	7 300	..	.97	..	..	
	500	....	..	.07	.04	..	
	500	....	..	.05	..	..	Applying pressure to rocker to bend bar and then removing pressure. Specimen removed.

Ordinate north at middle = .06 inch.
" west " = .03 "

Scale not disturbed.

CAMBRIA IRON COMPANY—TESTING LABORATORY.

JOHNSTOWN, PA., May, 1887.

DETAIL REPORTS OF COMPRESSION TESTS OF 1-INCH SQUARE IRON, SERIES K, WITH HINGED-ENDS.

Iron made by Union Iron Mills, Pittsburg, Pa.

EXPLANATIONS.

All tested as from rolls; not cold straightened.

Ends of bars were plane and rested on hinged rocker-bearings with lubricated pins, the bearing surface of which is in plane of axis of the pins.

Deviations were taken at middle of bar, and are referred to the straight line passing through center of ends of bar. Deviations given for load 00 were measured before putting bar into testing machine by applying a straight-edge. Deviations under load were obtained by measuring with a steel scale the ordinates from fine fish cords, stretched parallel to bar by means of a clamp at bottom, to which one end of cord was fastened, and a similar clamp at top carrying grooved pulleys over which the cords passed, with weights attached to overhanging ends. Deviations under no load and under initial load of 200 or 500 pound are assumed to be equal.

The tests were made on a vertical 300 000-pound Emery Testing Machine.

Axis of pins was in all cases east and west.

All bars, except a few of the longest ones, were scribed every inch on all four sides, and the inches are referred to by number beginning at bottom.

Marked end of bar was down in all cases.

Description of Specimen.	Load. Lbs.	Load. Lbs. per sq. in.	Deviations. N.	S.	E.	W.	Remarks.
				In.		In.	
Mark, K 4.	00	00	..	00	..	00	
	200	....	..	00	..	00	
Length, 11.98 in.	5 000	....	..	00	..	00	
	10 000	....	..	00	..	00	
Size,	20 000	....	..	00	..	00	
1.005 x .995 in.	30 000	....	..	00	..	00	
	31 000	....	..	00	..	00	
Slight shear mark	32 000	....	..	00	..	00	
at upper end.	32 900	32 900	..	00	..	00	Gone. Scaled at upper end.
	32 500	....	..	.005	..	00	
Ends square in	31 800	....	..	.04	..	00	
both directions.	31 700	....	..	.06	..	..	
				about			
	31 500	....	..	.07	..	..	
	32 400	32 400	..	.11	..	..	Scaled all along.
	32 000	....	..	.13	..	..	
	200	....	..	.15	..	00	
	5 000	....	..	.16	..	..	
	10 000	....	..	.16	..	..	
	15 000	....	..	.16	..	..	
	20 000	....	..	.16	..	..	
	25 000	....	..	.16	..	..	
	26 000	....	..	.16	..	..	
	27 000	....	..	.16	..	..	
	28 000	....	..	.16	..	..	
	29 000	....	..	.16	..	..	
	30 000	....	..	.18	..	..	Gone.
	29 500	....	..	.20	..	..	
	28 600	....	..	.23	..	..	Extent of rocking motion. Removed specimen.

Chord shortening = .12 inch.
East and west perfectly straight.

Shortening Per Inch.

North Side	1	2	3	4	5	6	7	8	9	10	11	12
	.0	.01	.01	.02	.025	.03	.025	.015	.015	.005	.005	.01
South Side	1	2	3	4	5	6	7	8	9	10	11	12
	.01	.01	.005	0	0	0	0	.005	.015	.015	.02	

Ordinates North.

At	1	2	3	4	5	6	7	8	9	10	11	inches.
	.06	.12	.18	.25	.27	.28	.25	.20	.14	.08	.04	

Description of Specimen.	Load. Lbs.	Load. Lbs. per sq. in.	Deviations. N.	S.	E.	W.	Remarks.
			In.			In.	
Mark, K—:	00	00	.01	..	..	.015	
	200	....	.01	..	..	.015	
Length, 15.98 in.	5 000	....	.01	..	..	.015	
	10 000	....	.01	..	..	.015	
Size,	15 000	....	.01	..	..	.015	
1.000 x 1.000 in.	20 000	....	.01	..	..	.015	
	25 000	....	.01	..	..	.015	
	26 000	....	.01	..	..	.015	
	27 000	....	.01	..	..	.015	
	28 000	....	.01	..	..	.015	
	29 000	....	01	..	..	....	
	30 000	....	.01	..	..	.015	
	31 000	....	.01	..	..	....	
	32 000	....	.01	..	..	....	
	33 000	....	.01	..	..	.025	
	34 000	....	.01	..	..	.025	
	34 300	34 300	.01	..	..	.065	Gone.
	32 000	32 000	.03	..	..	.075	
	31 400	....	.03	..	..	.095	
	31 000	....	.03	..	..	.155	
	30 900	....	.03	..	..	.295	
	200	....	.02	..	..	.305	
	5 000	....	.02	..	..	.325	
	10 000	....	.02	..	..	.325	
	15 000	....	.02	..	..	.335	
	20 000	....	.01	..	..	.335	
	25 000	....	.01	..	..	.335	Removed specimen.

Ordinate east at middle.. = .28 inch.
" south at middle. = .01 "
Chord shortening..... = .13 "

Shortening Per Inch.

East Side	1 to 5	6	7	8	9	10	11	12	13 to 16			
	0	.01	.01	.025	.025	.02	.01	.01	0			
West Side	1	2	3	4	5	6 to 12	13	14	15	16		
	.02	.02	.015	.005	.005	0	.01	.01.	.02	.02		

At	1	2	3	4	5	6	7	8	9	10	11	inches.
	.06	.12	.18	.25	.27	.28	.25	.20	.14	.08	.04	

West Side	1	2	3	4	5	6 to 12	13	14	15	16
	.02	.02	.015	.005	.005	0	.01	.01.	.02	.02

Description of Specimen	Load. Lbs.	Load. Lbs. per sq. in.	Deviations. N.	S.	E.	W.	Remarks.
				In.		In.	
Mark, K 1	00	00	..	00	..	.02	
	2 000	....	..	00	..	.02	
Length, 19.99 in.	5 000	....	..	.01	..	.02	
	10 000	....	..	.01	..	.02	
Size,	15 000	....	..	.01	..	.02	
1.003 x 1.000 in.	20 000	....	..	.01	..	.02	
	25 000	....	..	.01	..	.02	
	26 000	....	..	.01	..	.02	
	27 000	....	..	.01	..		
	28 000	....	..	.01	..		
	29 000	....	..	.01	..		
	30 000	....	..	.01	..	.02	
	31 000	....	..	.01	..		
	32 000	....	..	.01	..	.02	
	33 000	....	..	.015	..	.03	
	33 500	....	..	.015	..	.03	
	33 600	....	..	.02	..		
	34 000	....	..	.02	..	.04	
	35 000	34 910	..	.04	..	.10	Fails.
	30 000	....	..	.05	..	.17	
	29 000	....	..	.05	..	.19	
	28 600	....	..	.05	..	.21	
	28 000	....	..	.07	..	.28	
	27 000	....	..	.09	..	.38	
	26 000	....	..	.13	..	.45	
	25 000	....	..	.16	..	.50	
	200	....	..	.12	..	.44	
	2 000	....	..	.12	..	.45	
	5 000	....	..	.12	..	.45	
	10 000	....	..	.12	..	.46	
	15 000	....	..	.14	..	.47	
	20 000	....	..	.15	..	.49	Removed specimen.

Ordinate east at middle.. = .42 inch.
" north at middle = .10 "
Chord shortening..... = .10 "

Shortening Per Inch.

East Side	1 to 7	8	9	10	11	12	13	14	15 to 20
	0	.01	.01	.02	.02	.02	.02	.01	0

West Side	1	2	3	4 to 8	9	10	11	12	13 to 17	18	19	20
	.02	.02	.01	0	—.005	—.005	—.005	—.005	0	—.01	—.01	—.02

Description of Specimen.	Load. Lbs.	Load. Lbs. per sq. in.	Deviations. N.	S.	E.	W.	Remarks.
				In.	..	In.	
Mark, K 1:	00	....	..	00	..	00	
	200	....	..	00	..	00	
Length, 20.00 in.	5 000	...	..	.01	..	00	
	10 000	....	..	.01	..	00	
Size,	15 000	....	..	.01	..	00	
1.003 x 1.000 in.	20 000	....	..	.01	..	00	
	25 000	....	..	.01	..	00	
East and west straight.	26 000	....	..	.01	..	00	
	27 000	....	..	.01	..	..	
North and south straight.	28 000	....	..	.01	..	..	
	29 000	....	..	.01	..	00	
	30 000	....	..	.01	..	00	
	31 000	....	..	.01	..	00	
	32 000	....	..	.01	..	00	
	33 000	....	..	.02	..	00	
	34 000	33 910	..	.03	..	..	Going. Fails.
	31 500	....	..	.08	..	.01	
	20 000	....	..	.35	..	.02	
	200	....	..	.28	..	.01	
	5 000	....	..	.30	..	.01	
	10 000	....	..	.32	..	.01	
	15 000	....	..	.35	..	.01	
	16 000	....	..	.36	..	..	
	17 000	....	..	.37	..	..	
	18 000	....	..	.38	..	..	
	19 000	....	..	.40	..	..	Gone. Removed.

Ordinate north at middle = .33 inch.
" east " = .01 "
Chord shortening ..... = .04 "

Shortening Per Inch.

North Side	1 to 7	8	9	10	11	12	13	14 to 20
	0	0	.01	.02	.02	.01	.01	00

South Side	1	2 to 9	10	11	12	13	14 to 18	19	20
	.01	0	—.005	—.005	—.005	—.005	0	.01	.01

Description of Specimen.	Load. Lbs.	Load. Lbs. per sq. in.	Deviations. N.	S.	E.	W.	Remarks.
			In.		In.		
Mark, K 1·	00	....	.025	..	00	..	
	200	....	.025	..	00	..	
Length, 22.00 in.	5 000	....	.025	..	.01	..	
	10 000	....	.025	..	.01	..	
Size,	15 000	....	.015	..	.01	..	
1.003 × 1.000 in.	20 000	....	.015	..	.01	..	
	25 000	....	.015	..	.01	..	
Ordinate south,	26 000	....	.015	..	.01	..	
=.025.	27 000	....	.025	..	.01	..	
	28 000	....	.025	..	.01	..	
East and west	29 000	....	.025	..	..	..	
straight.	30 000	....	.025	..	.01	..	
	31 000	....	..	..	..	..	
	32 000	....	..	..	..	..	
	33 000	....	..	..	..	..	
	34 000	33 910	.035	..	.01	..	Going.
	20 000	19 940	.355	..	..	..	
	19 000	....	.415	..	..	..	
	18 000	....	.475	..	..	..	
	200	....	.365	..	00	..	
	5 000	....	.395	..	00	..	
	10 000	....	.425	..	00	..	
	15 000	....	.475	..	..	.01	Removed specimen.

Ordinate south at middle, = .38 inch.
" west " = .02 "
Chord shortening..... = .04 "

Shortening Per Inch.

South Side	1 to 7	8	9	10	11	12	13	14	15 to 22
	00	.01	.01	.01	.015	.015	.015	.01	0
North Side.	1 to 10	11	12	13 to 20		21	22		
	0	—.005	—.005	0		.01	.02		

Description of Specimen.	Load. Lbs.	Load. Lbs. per sq in.	Deviations. N.	S.	E.	W.	Remarks.
				In.		In.	
Mark, K 11·	00	00	..	.04	..	.02	
	200	....	..	.04	..	.02	
Length, 24.00 in.	5 000	....	..	.04	..	.02	
	10 000	....	..	.04	..	.02	
Size,	15 000	....	..	.03	..	.02	
1.006 × 1.003 in.	20 000	....	..	.05	..	.02	
	25 000	....	..	.03	..	.02	
Ordinates	26 000	....	..	.05	..	..	
East = .02	27 000	....	..	.06	..	..	
North = .04	28 000	....	..	.06	..	..	
	29 000	....	..	.06	..	..	
	30 000	....	..	.06	..	.02	
	31 000	....	..	.07	..	..	
	31 500	31 230	..	.09	..	..	Gone.
	17 000	16 850	..	.40	..	..	
	16 000	....	..	.45	..	..	
	16 000	....	..	.55	..	.06	
	200	....	..	.42	..	.06	
	5 000	....	..	.46	..	.06	
	10 000	....	..	.52	..	.06	Limit of rocking motion. Removed specimen.

Ordinate north at middle, = .48 inch.
" east " = .05 "
Chord shortening, ... = .04 "

Shortening Per Inch.

North Side.	1 to 8	9	10	11	12	13	14	15	16	17	18 to 24
	0	.01	.01	.01	.01	.01	.01	.01	.01	.005	0
South Side.	1	2 to 23		24							
	.02	0		.02							

Description of Specimen.	Load. Lbs.	Load. Lbs. per sq. in.	Deviations. N.	S.	E.	W.	Remarks.
				In.		In.	
Mark, K 2·	00	00	..	.02	..	.02	
Ordinates.	200	....	..	.02	..	.02	
East, = .02 in.	5 000	....	..	.02	..	.02	
North, = .02 in.	10 000	....	..	.02	..	.02	
	15 000	....	..	.02	..	.02	
	20 000	....	..	.02	..	.02	
Length, 26.02 in.	25 000	....	..	.03	..	.02	
	26 000	....	..	.03	..	..	
Size.	27 000	....	..	.03	..	..	
1.008 × 1.000 in.	28 000	....	..	.03	..	..	
	29 000	....	..	.03	..	..	
	30 000	....	..	.03	..	.02	
	31 000	....	..	.03	..	..	
	32 000	....	..	.03	..	..	
	33 000	....	..	.04	..	.02	Scaling.
	33 900	33 750	..	.05	..	..	Fails.
	14 700	14 590	..	.56	..	..	
	200	....	..	.38	..	.05	
	5 000	....	..	.44	..	.05	
	8 000	....	..	.48	..	..	
	10 000	....	..	.51	..	..	
	11 000	....	..	.52	..	..	
	12 000	....	..	.54	..	..	
	13 000	....	..	.56	..	..	Probably at limit of rocking motion.
	14 000	....	..	.58	..	..	
	15 000	....	..	.62	..	..	Scales rapidly. Piece removed.

Ordinate north at middle, = .52 inch.
" east " = .06 "
Chord shortening,..... = .04 "

Shortening Per Inch.

North Side.	1 to 9	10	11	12	13	14	15	16	17 to 26	
	0	.01	.01	.015	.015	.015	.015	.01	0	
South Side.	1 to 11	12	13	14	15 to 26					
	0	—.005	—.005	—.005	0					

Description of Specimen.	Load. Lbs.	Load. Lbs. per sq. in.	Deviations. N.	S.	E.	W.	Remarks.
				In.	In.		
Mark, K 3·	00	00	..	.02	.05	..	
	200	200	..	.02	.05	..	
Length, 28.01 in.	5 000	....	..	.02	.04	..	
	10 000	....	..	.02	.05	..	
Size,	15 000	....	..	.03	.05	..	
1.000 x 1.000 in.	20 000	....	..	.03	.05	..	
	25 000	....	..	.03	.04	..	
	26 000	....	..	.03	.04	..	
	27 000	....	..	.03	.05	..	
	28 000	....	..	.03	.05	..	
	29 000	....	..	.03	.05	..	
	30 000	....	..	.03	.07	..	
	31 000	....	..	.03	.07	..	
	32 000	32 000	..	.08	.09	..	Scaling. Gone. Bent east first, then south.
	14 000	14 000	..	.61	.25	..	
	200	....	..	.41	.23	..	
	5 000	....	..	.46	.23	..	
	10 000	....	..	.55	.23	..	
	11 000	....	..	.58	.23	..	
	12 000	....	..	.61	.23	..	
	13 000	....	..	.66	.23	..	Extent of rocking motion. Removed specimen.

Ordinate north at middle ..... = .50 inch.
" west " " ..... = .27 "
Chord shortening ..... = .05 "
Maximum shortening at center west side = .015 "

Shortening Per Inch.

North Side	1 to 9	10	11	12	13	14	15	16	17	18	19 to 28	
	0	.01	.01	.015	.015	.015	.015	.01	.01	.005	0	
South Side	1	2 to 11	12	13 to 27	28							
	.01	0	0	0	.01							

Description of Specimen.	Load. Lbs.	Load. Lbs. per sq. in.	Deviations. N.	S.	E.	W.	Remarks.
			In.			In.	
Mark, K 3:	00	00	.06	..	..	.04	
	200	....	.06	..	..	.04	
Length, 28.02 in.	5 000	....	.06	..	..	.05	
	10 000	....	.06	..	..	.05	
Size,	15 000	....	.07	..	..	.05	
1.000 x 1.000 in.	20 000	....	.08	..	..	.05	
	23 000	....	.08	..	..	..	
Twist, .04 in. left.	24 000	....	.08	..	..	..	
	25 000	....	.08	..	..	.06	
	26 000	....	.08	..	..	.06	
	27 000	...	.08	..	..	.06	
	28 000	....	.08	..	..	.06	
	29 000	....	.09	..	..	.06	
	30 000	....	.095	..	..	.07	
	30 700	30 700	..	..	..	..	Scaled on east side first. Fails.
	13 900	13 900	.63	..	..	.13	
	200	....	.42	..	..	.10	
	5 000	....	.46	..	..	.11	
	6 000	....	.48	..	..	.11	
	7 000	....	.49	..	..	.11	
	8 000	....	.52	..	..	.12	
	9 000	....	.53	..	..	.12	
	10 000	....	.55	..	..	.12	
	11 000	....	.58	..	..	.12	
	12 000	....	.60	..	..	.13	
	13 000	....	.62	..	..	.13	
	13 400	....	.66	..	..	.13	Extent of rocking motion. Removed specimen.

Ordinate south at middle = .49 inch.
" east " = .10 "
Chord shortening..... = .03 "

Shortening Per Inch.

South Side	1 to 10	11	12	13	14	15	16	17	18	19 to 28
	0	.005	.01	.015	.015	.01	.01	.01	.005	0
North Side	1 to 12	13	14	15	16					
	0	—.005	—.005	—.005	—.005					

Description of Specimen.	Load. Lbs.	Load. Lbs per sq. in.	Deviations. N.	S.	E.	W.	Remarks.
				In.		In.	
Mark, K 5:	00	00	..	.06	..	00	
	200	....	..	.06	..	00	
Length, 30.04 in.	5 000	...	..	.07	..	00	
	10 000	....	..	.07	..	00	
Size,	15 000	....	..	.08	..	00	
1.010 x 1.015 in.	20 000	....	..	.09	..	00	
	25 000	....	..	.10	..	00	
.06 in. twist left.	26 000	....	..	.10	..	00	
	27 000	....	..	.10	..	..	
	28 000	....	..	.10	..	..	
	29 000	....	..	.11	..	..	
	30 000	29 270	..	.12	..	..	Fails.
	13 000	12 780	..	.65	..	.02	
	200	....	..	.44	..	.03	
	5 000	....	..	.49	..	..	
	6 000	....	..	.52	..	..	
	7 000	....	..	.54	..	..	
	8 000	....	..	.56	..	..	
	9 000	....	..	.59	..	..	
	10 000	....	..	.62	..	..	
	11 000	....	..	.66	..	..	
	12 090	11 710	..	.76	..	..	Maximum and extent of rocking motion. Specimen removed.

Ordinate north at middle = .56 inch.
" east " = .03 "
Chord shortening ..... = .05 "

Shortening Per Inch.

North Side	1 to 13	14	15	16	17	18	19 to 30	
	0	.01	.01	.01	.01	.01	0	
South Side	1 to 12	13	14	15	16	17	18 to 30	
	0	—.005	—.005	—.005	—.005	—.005	0	

Description of Specimen.	Load. Lbs.	Load. Lbs. per sq. in.	Deviations. N.	S.	E	W.	Remarks.
			In.			In	
Mark, K 18·	00	00	.03	..	..	.02	
	200	....	.03	..	..	.02	
Length, 30.03 in.	5 000	....	.02	..	..	.02	
	10 000	....	.02	..	..	.02	
Size,	15 000	....	.03	..	..	.02	
1.005 x .995 in.	20 000	....	.03	..	..	.02	
	25 000	....	.03	..	..	.02	
	26 000	....	.03	..	..	.02	
	27 000	....	.03	..	..	.02	
	28 000	....	.03	..	..	..	
	29 000	....	.04	..	..	.02	
	30 000	....	.04	..	..	.02	
	31 000	....	.04	..	..	.02	
	32 000	....	.04	..	..	.01	
	33 000	33 000	.05	..	..	..	Going. Fails.
	12 000	12 000	.73	..	..	.02	
	200	....	.50	..	..	.03	
	5 000	....	.58	..	..	.02	
	6 000	....	.60	..	..	..	
	7 000	....	.63	..	..	..	
	8 000	....	.66	..	..	..	
	9 000	....	.69	..	..	..	
	10 000	....	.72	..	..	..	
	11 000	....	.73	..	..	..	Before 11 000, upper rocker had reached extent of motion. Removed specimen

Ordinate south at middle = .51 inch.
" west " = .01 "
Chord shortening ..... = .03 "

Shortening Per Inch.

South Side	1 to 13	14	15	16	17	18	19 to 30
	0	.01	.01	.01	.01	.01	0
North Side	1 to 13	14	15	16	17	18 to 30	
	0	—.005	—.005	—.005	—.005	0	

Description. of Specimen.	Load. Lbs.	Load. Lbs per sq. in.	Deviations. N.	S.	E.	W.	Remarks.
			In.	In.	In.		
Mark, K 3:	00	00	..	00	.02	..	
	200	....	..	00	.02	..	
Length, 32.00 in.	5 000	....	..	00	.02	..	
	10 000	....	..	.005	.02	..	
Size,	15 000	....	..	.005	.02	..	
1.000 x 1.000 in.	20 000	....	..	00	.02	..	
	25 000	....	..	00	.03	..	
Right hand twist .10	26 000	....	.01	..	.03	..	
in. on corners .06	27 000	....	00	00	.03	..	
in. at centers of	28 000	....	..	00	.03	..	
sides.	29 000	....	..	00	.03	..	
	30 000	....	..	00	.035	..	
Defect in bar from 8	31 000	....	..	00	.035	..	
to 12 in. on west	32 000	....	..	00	.04	..	
side.	33 000	....	..	00	.04	..	
	34 000	....	..	00	.04	..	
	34 900	34 900	..	.05	..	..	Fails. — These measurements at middle, but maximum deviation is at 13 in.
	24 900	24 900	..	..	.32	..	
	13 000	....	..	.50	.39	..	
	200	....	..	.26	.31	..	
	200	....	..	.29	.34	..	These taken at 13 in. as are following measurements.
	5 000	....	..	.32	.34	..	
	6 000	....	..	.33	.35	..	
	7 000	....	..	.34	.36	..	
	8 000	....	..	.36	.36	..	
	9 000	....	..	.38	.36	..	
	10 000	....	..	.41	.38	..	
	11 000	....	..	.45	.38	..	
	12 000	....	..	.47	.38	..	
	13 000	....	..	.52	.41	..	
	13 500	13 500	..	.58	.41	..	Gone. Specimen removed.

Ordinate north, maximum at 13 inch = .35 inch.
" east " " = .31 "
Chord shortening..... = .05 "

Shortening Per Inch.

North Side	1 to 10	11	12	13	14	15	16	17	18 to 32
	0	.01	.01	.01	.01	.01	.01	.01	0
South and East Sides	Lengthening on south side is not perceptible. Maximum shortening on east side is .01 in. per inch.								

Description of Specimen.	Load. Lbs.	Load. Lbs. per sq. in.	Deviations. N.	S.	E.	W.	Remarks.
Mark, K 4·	00	00	..	00	..	.04	
	200	....	..	0	..	.04	
Length, 33.95 in.	5 000	....	..	00	..	.03	
	10 000	....	..	00	..	.03	
No twist.	15 000	....	..	.01	..	.03	
	20 000	....	..	.01	..	.04	
Size.	25 000	....	..	.02	..	.04	
1.005 x .997 in.	26 000	....	..	.02	..	.04	
	27 000	....	..	.02	..	.04	
	28 000	....	..	.02	..	.04	
	29 000	....	..	.02	..	.04	
	30 000	....	..	.03	..	.05	
	31 000	....	..	.04	..	.07	
	31 000	30 940	..	..	..	..	Gone.
	10 000	9 980	..	.76	..	..	
	200	....	..	.44	..	.09	
	5 000	....	..	.54	..	.09	
	6 000	....	..	.58	..	..	
	7 000	....	..	.61	..	..	
	8 000	....	..	.65	..	..	
	9 000	....	..	.70	..	..	
	9 800	9 780	..	.76	..	..	Extent of rocking motion. Removed specimen.

Ordinate north at middle = .44 inch.
" east " = .07 "
Chord shortening..... = .02 "

Shortening Per Inch.

North Side	1 to 13	14	15	16	17	18	19	20	21	22 to 34
	0	.005	.005	.01	.01	.01	.01	.005	.005	0
South Side	1 to 15	16		17		18	19	20 to 34		
	0	—.005		—.005		—.005	—.005	00		

Description of Specimen.	Load. Lbs.	Load. Lbs. per sq. in.	Deviations. N.	S.	E.	W.	Remarks.
				In.	In.		
Mark, K 4:	00	00	..	.05	.04	..	
	200	....	..	.05	.04	..	
Length, 33.96 in.	5 000	....	..	.05	.03	..	
	10 000	....	..	.06	.03	..	
Size.	15 000	....	..	.07	.03	..	
1.005 x .997 in.	20 000	....	..	.08	.03	..	
	21 000	....	..	.09	.03	..	
Twist, .03 in.	22 000	....	..	.09	.03	..	
	23 000	....	..	.09	.03	..	
	24 000	....	..	.10	.03	..	
	25 000	....	..	.11	.03	..	
	26 000	26 000	..	.13	.03	..	Going slowly.
	12 200	12 200	..	.57	..	..	Went very slowly. Scale slightly disturbed at middle of north side.
	200	....	..	.29	.02	..	
	1 000	....	..	.30	.02	..	
	2 000	....	..	.31	..	..	
	3 000	....	..	.32	..	..	
	4 000	....	..	.33	..	..	
	5 000	....	..	.34	..	..	
	6 000	....	..	.36	..	..	
	7 000	....	..	.39	..	..	
	8 000	....	..	.41	..	..	
	9 000	....	..	.43	..	..	
	10 000	....	..	.48	..	..	
	11 000	....	..	.52	..	..	
	12 000	....	..	.57	..	..	
	12 500	....	..	.63	..	..	
	10 900	....	..	.73	..	..	
	200	....	..	.41	..	..	Specimen removed.

Ordinate north at middle..... = .40 inch.
" east and west at middle = 00 "
Chord shortening..... = .03 "
The middle 8 inches on north side shortened altogether .03 inch.
" 8 " south " lengthened " .02 "

Description of Specimen.	Load. Lbs.	Load. Lbs. per sq. in.	Deviations. N.	S.	E.	W.	Remarks.
				In.	In.	In.	
Mark, K 4·	00	00	..	.06	..	.03	
	200	....	..	.06	..	.03	
Length, 36.04 in.	5 000	....	..	.07	..	.01	
	10 000	....	..	.08	..	00	
Left-hand twist = .03 in.	15 000	....	..	.10	..	..	
	16 000	....	..	.11	.01	..	
	17 000	....	..	.11	.01	..	
Size,	18 000	....	..	.12	.01	..	
1.010 x .995 in.	19 000	....	..	.12	.01	..	
	20 000	....	..	.13	.01	..	
	21 000	20 900	..	..	..	..	Gone. Scales slightly on north side.
	14 000	13 930	..	.53	..	..	
	200	....	..	.20	..	.01	
	5 000	....	..	.25	.01	..	
	6 000	....	..	.26	.01	..	
	7 000	....	..	.26	.01	..	
	8 000	....	..	.29	.01	..	
	9 000	....	..	.32	.01	..	
	10 000	....	..	.33	00	..	
	11 000	....	..	.38	00	..	
	12 000	....	..	.43	00	..	
	12 980	12 920	..	.56	00	..	Removed specimen.

Ordinate north at middle = .29 inch.
" east " = 00 "
Chord shortening..... = .01 "

Shortening Per Inch.

North Side	16	17	18	19	20	21
	.01	.01	.01	.01	.01	.01

South Side uncertain.

Description of Specimen.	Load. Lbs.	Load. Lbs. per sq. in.	Deviations. N.	S.	E.	W.	Remarks.
			In.			In.	
Mark, K 4:	00	00	.03	..	..	.04	
	200	....	.03	..	..	.04	
Length, 36.04 in.	5 000	....	.04	..	..	.04	
	10 000	....	.05	..	..	.04	
Size,	15 000	....	.05	..	..	.04	
1.010 x .995 in.	20 000	19 900	..	..	..	..	Gone. Went rather slowly.
	13 000	12 930	..	..	..	..	
	11 200	11 140	.64	..	..	.03	
	200	....	.30	..	..	.03	
	1 000	....	.30	..	..	..	
	2 000	....	.32	..	..	..	
	3 000	....	.33	..	..	..	
	4 000	....	.35	..	..	..	
	5 000	....	.37	..	..	..	
	6 000	....	.40	..	..	..	
	7 000	....	.44	..	..	..	
	8 000	....	.47	..	..	..	
	9 000	....	.52	..	..	..	
	10 000	....	.57	..	..	..	
	11 000	....	.66	..	..	..	
	11 300	11 240	..	..	..	..	Gone.
	10 300	....	.83	..	..	..	
	10 200	....	.88	..	..	..	
	200	....	.51	..	..	..	Removed specimen.

Ordinate south at middle = .52 inch.
" east " = .04 "
Chord shortening..... = .02 "

Shortening Per Inch.

South Side	1 to 15	16	17	18	19	20	21	22 to 36
	0	.0066	.0066	.0066	.0066	.0066	.0066	0

Description of Specimen.	Load. Lbs.	Load. Lbs. per sq. in.	Deviations. N.	S.	E.	W.	Remarks.
				In.	In.		
Mark K, 5:	00	00	..	.02	.02	..	
	200	....	..	.02	.02	..	
Length, 38.00 in.	5 000	....	..	.02	.01	..	
	10 000	....	..	.03	.01	..	
Size,	15 000	....	..	.03	.01	..	
1.010 x 1.010 in.	20 000	....	..	.04	.01	..	
	21 000	....	..	.04	..	..	
	22 000	....	..	.05	.01	..	
	23 000	....	..	.05	.02	..	
	24 000	23 320	..	.07	..	..	Gone suddenly.
	11 500	11 220	..	.60	..	..	
	200	....	..	.24	.02	..	
	1 000	....	..	.25	..	..	
	2 000	....	..	.25	..	..	
	3 000	....	..	.27	..	..	
	4 000	....	..	.29	..	..	
	5 000	....	..	.31	..	..	
	6 000	....	..	.33	..	..	
	7 000	....	..	.35	..	..	
	8 000	....	..	.39	..	..	
	9 000	....	..	.43	..	..	
	10 000	....	..	.49	..	..	
	11 000	....	..	.56	..	..	
	11 800	11 510	..	.67	..	..	
	10 200	....	..	.75	..	..	
	200	....	..	.27	.01	..	Removed specimen.

Ordinate north at middle = .37 inch.
" west " = .03 "
Chord shortening..... = .01 "

Shortening Per Inch.

North Side	1 to 17	18	19	20	21	20 to 38
	0	.0067	.0067	.0067	.0067	0

Description of Specimen.	Load Lbs.	Load. Lbs. per sq. in.	Deviations. N.	S.	E.	W.	Remarks.
			In.			In.	
Mark, K 5·	00	00	00	..	..	.03	
	200	....	00	..	..	.03	
Length, 38.02 in.	5 000	....	00	..	..	.04	
	10 000	....	00	..	..	.05	
Size,	15 000	....	00	..	..	.05	
1.010 x 1.015 in.	16 000	....	00	..	..	.05	
	17 000	....	00	..	..	.05	
Fairly straight.	18 000	....	00	..	..	.06	
	19 000	....	.005	..	..	.06	
No twist.	20 000	....	.005	..	..	.06	
	21 000	....	.005	..	..	.06	
	22 000	....	.01	..	..	.06	
	23 000	....	.01	..	..	.06	
	24 000	....	.01	..	..	.06	
	25 000	....	.01	..	..	.06	
	26 000	....	.01	..	..	.07	
	27 000	....	.02	..	..	.07	
	28 000	....	.02	..	..	.08	
	29 000	....	.02	..	..	.08	
	30 000	....	.03	..	..	.08	
	31 000	....	.03	..	..	.09	
	31 800	31 020	..	..	..	..	
	9 400	9 170	..	..	..	.19	
	6 500	....	.90	..	..	..	
	200	....	.57	..	..	.15	Max. deviation at 18 in.
	1 000	....	.57	..	..	..	do. do.
	2 000	....	.60	..	..	..	do. do.
	3 000	....	.64	..	..	..	do. do.
	4 000	....	.67	..	..	..	do. do.
	5 000	....	.72	..	..	..	do. do.
	6 000	....	.78	..	..	..	do. do.
	7 000	....	.87	..	..	..	do. do.
							Extent of rocking motion. Specimen removed.

Ordinate south, maximum at 18 inches = .60 inch.
" west, maximum " = .12 "
Chord shortening..... = .04 "

Shortening Per Inch.

North Side	1 to 14	15	16	17	18	19	20	21	22	23 to 38
	.0	.01	.01	.01	.01	.01	.01	.005	.005	0

South Side.—Lengthening not perceptible.

Description of Specimen.	Load. Lbs.	Load. Lbs. per sq. in.	Deviations. N.	S.	E.	W.	Remarks.
			In.			In.	
Mark, K 14	00	00	00	..	..	.03	
	200	....	00	..	..	.03	
Length, 40.00 in.	5 000	....	00	..	..	.02	
	10 000	....	.01	..	..	.02	
Size,	15 000	....	.03	..	..	.03	
1.006 x 1.000 in.	16 000	....	.03	..	..	.03	
	17 000	....	.04	..	..	.03	
	18 000	....	.05	..	..	.03	
	19 000	18 890	.07	..	..	..	Went rather suddenly.
	11 500	11 430	.49	..	..	.01	
	200	....	.11	..	..	..	
	1 000	....	.13	..	..	..	
	2 000	....	.13	..	..	..	
	3 000	....	.14	..	..	..	
	4 000	....	.14	..	..	..	
	5 000	....	.16	..	..	..	
	6 000	....	.17	..	..	..	
	7 000	....	.19	..	..	..	
	8 000	....	.21	..	..	..	
	9 000	....	.25	..	..	..	
	10 000	....	.30	..	..	..	
	11 000	....	.37	..	..	..	
	11 700	11 630	.56	..	..	..	
	10 600	....	.59	..	..	..	
	200	....	.17	..	..	00	Removed specimen.

Ordinate south, at middle = .22 inch.
" east " = .03 "
Chord shortening..... = .01 "

Shortening Per Inch.

South Side	1 to 17	18	19	20	21	22	23	24 to 40
	0	.0017	.0017	.0017	.0017	.0017	.0017	0

Description of Specimen.	Load. Lbs.	Load. Lbs. per sq. in.	Deviations. N.	S.	E.	W.	Remarks.
				In.	In.		
Mark, K 5	00	00	..	00	00	..	
	200	....	..	00	00	..	
Length, 40.01 in.	5 000	....	..	00	00	..	
	10 000	....	..	00	00	..	
Size,	15 000	....	..	.01	.01	..	
1.005 x 1.000 in.	20 000	....	..	.01	.01	..	
	21 000	....	..	.01	.01	..	
Right hand twist =	22 000	....	..	.01	.01	..	
.10 in.	23 000	....	..	.01	.01	..	
	24 000	....	..	00	.01	..	
	25 000	....	..	00	.01	..	
	26 000	....	..	00	.01	..	
	27 000	....	..	00	.01	..	
	28 000	....	..	00	.01	..	
	29 000	....	..	00	.01	..	
	30 000	....	.02	..	.01	..	
	31 000	30 000	.04	..	..	..	Went suddenly.
	9 000	8 930	.88	..	..	..	
	200	....	.43	..	.02	..	
	1 000	....	.43	..	..	..	
	2 000	....	.46	..	..	..	
	3 000	....	.50	..	..	..	
	4 000	....	.54	..	..	..	
	5 000	....	.59	..	..	..	
	6 000	....	.63	..	..	..	
	7 000	....	.74	..	..	..	
	8 000	....	.83	..	..	..	
	9 000	....	.89	..	..	..	Extent of rocking motion.
	200	....	.44	..	..	..	Removed specimen.

Ordinate south at middle = .46 inch.
" west " = .05 "
Chord shortening..... = .01 "

Shortening Per Inch.

South Side	1 to 18	19	20	21	22	23 to 40
	0	.005	.005	.005	.005	0

Description of Specimen.	Load. Lbs.	Load. Lbs. per sq. in.	Deviations. N.	S.	E.	W.	Remarks.
			In.			In.	
Mark, K 6·	00	00	00	..	..	.04	
	500	....	00	..	..	.04	
Length, 42.01 in.	5 000	....	00	..	..	.04	
	10 000	....	.01	..	..	.04	
Size,	15 000	....	.02	..	..	.05	
.997 x 1.005 in.	16 000	....	.02	..	..	.05	
	17 000	....	.03	..	..	.05	
	18 000	18 000	.04	..	..	..	Gone.
	12 700	12 700	.43	..	..	..	Rockers free.
	500	....	.02	..	..	.04	
	5 000	....	.03	..	..	.04	
	10 000	....	.06	..	..	.04	
	11 000	....	.07	..	..	.04	
	12 000	....	.10	..	..	.05	
	13 000	13 000	..	..	..	..	Going.
	12 700	....	.33	..	..	..	
	500	....	.03	..	..	.04	Removed specimen.

Ordinate south at middle = .03 inch.
" east " = .03 "
Chord shortening..... = .01 "
Shortening per inch not perceptible.

Description of Specimen.	Load. Lbs.	Load. Lbs. per sq. in.	Deviations. N.	S.	E.	W.	Remarks.
			In.		In.		
Mark, K 6:	00	00	.04	..	.04	..	
	500	....	.04	..	.04	..	
Length, 42.01 in.	5 000	....	.05	..	.05	..	
	10 000	....	.06	..	.05	..	
Size,	11 000	....	.07	..	.05	..	
1.007 x 1.000 in.	12 000	....	.07	..	.05	..	
	13 000	....	.08	..	.05	..	
	14 000	....	.09	..	.05	..	
	14 700	14 600	..	..	..	..	Went very slowly.
	13 000	12 910	.39	..	..	..	
	500	....	.05	..	.04	..	
	500	....	.05	..	.04	..	Placed .03 in. south of axis.
	5 000	....	.05	..	.05	..	
	10 000	....	.06	..	.05	..	
	11 000	....	.06	..	.05	..	
	12 000	....	.06	..	.05	..	
	13 000	....	.07	..	.05	..	
	14 000	....	.07	..	.05	..	
	15 000	....	.07	..	.05	..	
	16 000	....	.07	..	.05	..	
	17 000	....	.08	..	.05	..	
	18 000	....	.08	..	.05	..	
	19 000	....	.08	..	.04	..	
	20 000	....	.09	..	.04	..	
	21 000	....	.10	..	.04	..	
	22 000	21 850	.11	..	..	..	Gone suddenly. Rocker free.
	10 800	10 730	.74	..	..	..	
	500	....	.22	..	.05	..	
	5 000	....	.27	..	.05	..	
	6 000	....	.29	..	..	..	
	7 000	....	.32	..	..	..	
	8 000	....	.37	..	..	..	
	9 000	....	.43	..	.04	..	
	10 000	....	.56	..	..	..	
	10 700	10 630	..	..	..	..	Fails.
	10 000	....	.82	..	..	..	Scale drops on south side.
	500	....	.30	..	.03	..	Removed specimen.

Ordinate south at middle = .29 inch.
" west " = .03 "
Chord shortening..... = .01 "
Scale disturbed over middle 10 inches on south side.
Middle 8 inches on south side shorten .015 inch.
Middle 8 inches on north side apparently lengthened .01 inch.

Description of Specimen.	Load. Lbs.	Load. Lbs per sq. in.	Deviations. N.	S.	E.	W.	Remarks.
				In.			
Mark, K 7·	00	00	..	.07	..	00	
	500	....	..	.07	..	00	
Length, 44 04 in.	5 000	....	..	.10	..	00	
	10 000	....	..	.23	..	00	
Size,	11 000	....	..	.37	..	..	Going slowly.
.995 x 1.002 in.	11 000	....	..	.43	..	..	
	11 000	11 000	..	.47	..	..	Fails.
	9 400	....	..	.66	..	..	
	500	....	..	.18	..	00	
	500	....	..	.17	..	..	By applying pressure in direction to diminish deviation and releasing pressure.
	5 000	....	..	.25	..	..	
	6 000	....	..	.29	..	..	
	7 000	....	..	.44	..	..	
	8 000	....	..	.51	..	..	
	9 000	....	..	.54	..	..	
	9 600	9 600	..	.75	..	..	Fails slowly.
	9 000	....	..	.77	..	..	
	500	....	..	.24	..	00	Specimen removed.

Ordinate north, at middle..... = .24 inch.
" west, " ..... = .01 "
Chord shortening..... = .01 "
Shortening in middle four inches north side. = .01 "

Description of Specimen.	Load. Lbs.	Load. Lbs. per sq. in.	Deviations. N.	S.	E.	W.	Remarks.
				In.	In.		
Mark, K 7:	00	00	..	.03	.02	..	
	500	....	..	.03	.02	..	
Length, 44.04 in.	5 000	....	..	.03	.03	..	
	10 000	....	..	.03	.03	..	
Size,	11 000	....	..	.03	.03	..	
1.002 x 995 in.	12 000	....	..	.03	.03	..	
	13 000	....	..	.03	.03	..	
Specimen curved	14 000	....	..	.03	.03	..	
east and west like	15 000	....	..	.03	.03	..	
letter S.	16 000	....	..	.03	.03	..	
	17 000	....	..	.03	.03	..	
Ordinates	18 000	....	..	.03	.03	..	
west at	19 000	....	..	.04	.03	..	
0....=.06 in.	20 000	....	..	.04	.03	..	
11....=.00 "	21 000	....	..	.04	.03	..	
22....=.02 "	22 000	....	..	.04	.03	..	
33....=.03 "	23 000	....	..	.04	.04	..	
44....=.0 "	24 000	....	..	.04	.04	..	
	25 000	....	..	.04	.04	..	
	26 000	....	..	.04	.04	..	
	27 000	....	..	.05	.05	..	
	28 000	28 000	..	.08	..	..	Failed.
	8 000	....	..	.97	..	..	Extent of rocking motion.
	500	....	..	.46	..	..	
	1 000	....	..	.48	..	..	
	2 000	....	..	.49	..	..	
	3 000	....	..	.55	..	..	
	4 000	....	..	.61	..	..	
	5 000	....	..	.67	..	..	
	6 000	....	..	.77	..	..	
	7 000	....	..	.90	..	..	Extent of motion.
	500	....	..	.47	..	..	Removed specimen.

After Specimen Removed:

Ordinate north at middle..... = .45 inch.
" west at 0..... = .07 "
" " 11..... = 0 "
" " 22..... = .03 "
" " 33..... = .04 "
" " 44..... = 0 "
Chord shortening..... = .02 "
Shortening in middle six inches, north side = .015 "

Description of Specimen.	Load. Lbs.	Load. Lbs. per sq. in.	Deviations. N.	S.	E.	W.	Remarks.
			In		In.		
Mark, K 8·	00	00	00	..	.01	..	
	500	....	00	..	.01	..	
Length, 48.00 in.	5 000	....	.01	..	.01	..	
	10 000	....	.02	..	.01	..	
Size,	14 200	14 120	..	..	..	..	Failed.
1.000 x 1.006 in.	10 700	10 640	.44	..	..	..	
	500	....	.01	..	.01	..	
	500	....	00	..	.01	..	Placed .01 in. south of axis.
	5 000	....	.01	..	.01	..	
	10 000	....	.02	..	.02	..	
	11 000	....	.03	..	00	..	
	12 000	....	.03	..	00	..	
	13 000	....	.03	..	00	..	
	14 000	....	.03	..	00	..	
	15 000	....	.04	..	00	..	
	16 000	....	.04	..	00	..	
	17 000	....	.04	..	00	..	
	18 000	....	.05	..	00	..	
	18 600	18 490	..	..	..	..	Failed.
	9 600	9 550	.69	..	..	..	Rocker free.
	500	....	.06	..	.02	..	
	5 000	....	.08	..	..	..	
	6 000	....	.09	..	..	..	
	7 000	....	.10	..	..	..	
	8 000	....	.11	..	..	..	
	9 000	....	.12	..	..	..	
	10 000	....	.16	..	..	..	
	10 700	10 640	..	..	..	..	Failed.
	10 200	....	.43	..	..	..	
	500	....	.06	..	.01	..	Specimen removed.

Ordinate north at middle..... = .06 inch.
" east " ..... = .01 " "
Chord shortening..... = .00 "
Shortening per inch not perceptible.

Description of Specimen.	Load. Lbs.	Load. Lbs. per sq. in.	Deviations. N.	S.	E.	W.	Remarks.
			In.	In.	In.	In.	
Mark, K 9·	00	00	..	.05	.04	..	
	500	....	..	.05	.04	..	
Length, 52.00 in.	1 000	....	..	.05	.04	..	
	2 000	....	..	.05	.04	..	
Size,	3 000	....	..	.05	.04	..	
.995 x 1.005 in.	4 000	....	..	.05	.04	..	
	5 000	....	..	.06	.04	..	
	6 000	....	..	.06	.04	..	
	7 000	....	..	.06	.04	..	
	8 000	....	..	.07	.04	..	
	9 000	....	..	.07	.04	..	
	10 000	....	..	.08	.04	..	
	11 000	....	..	.09	.04	..	
	12 000	....	..	.09	.04	..	
	13 000	....	..	.09	.04	..	
	14 000	....	..	.11	.04	..	
	15 000	15 000	..	..	..	..	Failed.
	8 300	8 300	..	.68	..	..	
	500	....	..	.08	.04	..	
	5 000	....	00	00	.04	..	While load is rising to 5 000, pressure is put on rocker in direction to correct deviation.

(*Mark K 9· continued.*)

Description of Specimen.	Load. Lbs.	Load. Lbs. per sq. in.	Deviations. N.	S.	E.	W.	Remarks.
				In.			
Mark, K 9·	10 000	....	00	..	.04	..	
	11 000	....	00	..	..	..	
Length, 52.00 in.	12 000	....	.01	..	..	..	
	13 000	....	.01	..	..	..	
Size.	14 000	....	.01	..	..	..	
.995 x 1.005 in.	15 000	....	.02	..	..	..	
	16 000	....	.02	..	..	..	
	17 000	....	.02	..	..	..	
	18 000	....	.03	..	..	..	
	19 000	....	.04	..	..	..	Going.
	19 000	....	.06	..	..	..	
	19 700	19 700	..	..	..	..	Failed.
	8 500	8 500	.82	..	..	..	Rockers free.
	500	....	.04	..	.04	..	
	5 000	....	.06	..	.03	..	While load is rising to 5 000, pressure is put on rockers in direction to correct deviation.
	6 000	....	.07	..	..	..	
	7 000	....	.08	..	..	..	
	8 000	....	.09	..	..	..	
	9 000	....	.15	..	..	..	
	9 600	9 600	..	..	..	..	Failed.
	8 700	8 700	.37	..	..	..	
	500	....	.04	..	..	..	
	5 000	....	..	.01	..	..	By pressure on rockers while load rises to 4 000.
	6 000	....	..	.01	..	..	
	7 000	....	..	.01	..	..	
	8 000	....	..	.01	..	..	
	9 000	....	..	..	..	..	
	10 000	....	..	..	..	..	
	11 000	....	.01	..	..	..	
	12 000	....	.01	..	..	..	
	13 000	....	.02	..	..	..	
	14 000	....	.03	..	..	..	
	14 900	....	..	..	..	..	Gone. Same direction as above.
	10 700	....	..	..	..	..	
	500	....	.04	..	..	..	
	10 000	....	..	.33	..	..	By pressure on rockers while load rises to 10 000.
	6 500	....	..	.09	..	..	Releasing pressure while load drops to 6 500.
	10 000	....	..	.10	..	..	
	11 000	....	..	.11	..	..	
	12 000	....	..	.11	..	..	
	13 000	....	..	.12	..	..	
	14 000	....	..	.13	..	..	
	15 000	....	..	.14	..	..	
	16 000	....	..	.15	..	..	
	16 900	16 900	..	..	..	..	Failed.
	8 200	....	..	.78	..	..	
	500	....	..	.09	.04	..	Specimen removed.

After Removing Specimen.

Ordinate north at middle = .06 inches.
" west " = .03 inch.
Chord shortening ..... = 00 "
Scale undisturbed.

Description of Specimen.	Load. Lbs.	Load. Lbs. per sq. in.	Deviations.				Remarks.
			N.	S.	E.	W.	
				In.		In.	
Mark, K 9:	00	00	..	.06	..	.05	
	500	....	..	.06	..	.05	
Length, 52.00 in.	5 000	....	..	.07	..	.05	
	6 000	....	..	.08	..	..	
Size,	7 000	....	..	.08	..	.05	
.995 x 1.005 in.	8 000	....	..	.09	..	..	
	9 000	....	..	.10	..	..	
	10 000	....	..	.11	..	..	
	11 000	....	..	.12	..	..	
	12 000	12 000	..	..	..	..	Failed.
	9 100	9 100	..	.46	..	..	
	500	....	..	.07	..	.05	
	500	....	..	.06	..	.05	Specimen placed .06 in. north of axis.
	5 000	....	..	.04	..	.05	
	6 000	....	..	.03	..	..	
	7 000	....	..	.02	..	..	
	8 000	....	.02	..	..	..	
	8 700	8 700	..	..	..	..	Went very slowly.
	8 500	8 500	.30	..	..	..	
	500	....	..	.05	..	..	
	500	....	..	.06	..	.05	Specimen placed .04 in. north of axis.
	5 000	....	..	.05	..	.05	
	6 000	....	..	.05	..	.05	
	7 000	....	..	.04	..	.05	
	8 000	....	..	.04	..	..	
	9 000	....	..	.04	..	..	
	10 000	....	..	.04	..	..	
	11 000	....	..	.03	..	.06	
	12 000	12 000	..	..	..	..	Failed.
	8 800	8 800	.35	..	..	..	
	500	....	..	.05	..	.05	
	500	....	..	.06	..	.05	Specimen placed .02 in. north of axis.
	5 000	....	..	.06	..	.05	
	7 000	....	..	.06	..	..	
	8 000	....	..	.07	..	..	
	9 000	....	..	.07	..	..	
	10 000	....	..	.08	..	..	
	11 000	....	..	.08	..	..	
	12 000	....	..	.08	..	..	
	13 000	....	..	.09	..	..	
	14 000	....	..	.09	..	..	
	15 000	....	..	.10	..	..	
	16 000	....	..	.11	..	..	
	17 000	....	..	.12	..	..	
	18 000	....	..	.14	..	..	
	18 200	18 200	..	..	..	..	Failed.
	8 400	8 400	..	.89	..	..	Rockers free.
	500	....	..	.13	..	.05	Specimen removed.

Ordinate north at middle = .13 inch.
" east " = .05 "
Chord Shortening..... = 00 "

Scale very slightly disturbed middle of north side.

Description of Specimen.	Load. Lbs.	Load. Lbs. per sq. in.	Deviations. N.	S.	E.	W.	Remarks.
			In.	In.	In		
Mark, K 10:	00	00	..	.01	.07	..	
	500	....	..	.01	.07	..	
Length, 56.01 in.	5 000	....	..	.02	.05	..	
	6 000	....	..	.02	.05	..	
Size,	7 000	....	..	.02	.05	..	
.998 x 1.002 in.	8 000	....	..	.02	.05	..	
	9 000	....	..	.02	.05	..	
	10 000	....	..	.02	.05	..	
	11 000	....	..	.03	.05	..	
	12 000	....	..	.03	.05	..	
	13 000	....	..	.04	.06	..	
	14 000	....	..	.04	.06	..	
	15 000	....	..	.05	.06	..	
	16 000	....	..	.06	.07	..	
	17 000	....	..	.07	.07	..	
	17 500	17 500	..	..	..	..	Failed.
	7 600	7 600	..	.86	..	..	Went very suddenly.
	500	....	..	.06	.07	..	
	5 000	....	.04	..	.06	..	By pressure on rockers in direction to correct deviation and while load rises to 5 000.
	6 000	....	.05	..	.05	..	
	7 000	....	.05	..	.05	..	
	8 000	....	.05	..	.06	..	
	9 000	....	.06	..	.06	..	
	10 000	....	.06	..	.06	..	
	11 000	....	.07	..	.06	..	
	12 000	....	.08	..	.06	..	
	13 000	....	.09	..	.07	..	
	13 900	13 900	..	..	..	..	Failed.
	7 500	7 500	.69	..	..	..	Rockers free.
	500	....	.01	..	.07	..	
	500	....	..	.01	.07	..	
	5 000	....	..	.01	.05	..	
	6 000	....	..	.02	.05	..	
	7 000	....	..	.02	.05	..	
	8 000	....	..	.02	.05	..	
	9 000	....	..	.02	.05	..	
	10 000	....	..	.03	.05	..	
	11 000	....	..	.03	.05	..	
	12 000	....	..	.04	.05	..	
	13 000	....	..	.04	.06	..	
	14 000	....	..	.04	.06	..	
	15 000	....	..	.05	.06	..	
	16 000	....	..	.06	.07	..	
	17 000	17 000	..	..	..	..	Failed.
	7 400	7 400	..	.83	..	..	
	500	....	..	.06	.07	..	
	5 000	....	..	.08	.06	..	
	6 000	....	..	.10	.06	..	
	7 000	....	..	.11	.06	..	
	8 000	....	..	.12	.06	..	
	9 000	....	..	.13	.05	..	
	9 900	....	..	..	..	..	
	7 900	....	..	.42	..	..	
	500	....	..	.06	.08	..	
	5 000	....	..	.04	..	..	By pressure on rockers while load rises to 5 000.
	6 000	....	..	.04	.06	..	
	7 000	....	..	.05	.06	..	
	8 000	....	..	.05	.06	..	
	9 000	....	..	.06	.06	..	
	10 000	....	..	.06	.06	..	
	11 000	....	..	.07	.06	..	

(*Mark K* 10: *continued.*)

Description of Specimen.	Load. Lbs.	Load. Lbs. per sq. in.	Deviations. N.	S.	E.	W.	Remarks.
Mark, K 10:				In.	In.		
Length, 56.01 in.	12 000	....	..	.08	.06	..	
	13 000	13 000	..	.11	..	..	Failed.
Size,	6 900	6 900	..	.68	..	..	
.998 x 1.002 in.	500	....	..	.06	.08	..	Specimen removed.

Before Testing.

Ordinates north { 14 / .02 | 28 / .01 | 42 / 0 | 56 inches. / 0 inch.

" west..... { 28 / .07 | 42 / .11 | 14 inches. / .02 inch.

After Specimen Removed.

Ordinates north { 14 / .04 | 28 / .05 | 42 inches. / .02 inch.

" west. { 14 / .02 | 28 / .07 | 42 inches. / .10 inch.

Description of Specimen.	Load. Lbs.	Load. Lbs. per sq. in.	Deviations. N.	S.	E.	W.	Remarks.
			In.			In.	
Mark, K 10·	00	00	.04	..	..	.08	
	500	....	.04	..	..	.08	
Length, 56.01 in.	5 000	....	.08	..	..	.08	
	6 000	....	.09	..	..	.08	
Size,	7 000	....	.11	..	..	.09	
.998 x 1.002 in.	8 000	8 000	..	..	..	..	Went very slowly.
	7 500	7 500	.47	..	..	.11	
	500	....	.06	..	..	.09	
	5 000	....	.09	..	..	.09	
	6 000	....	.10	..	..	.09	
	7 000	....	.13	..	..	.09	
	8 000	8 000	.23	..	..	..	Went very slowly.
	7 500	7 500	.44	..	..	.11	
	500	....	.06	..	..	.08	Specimen removed.

Ordinate south at middle = .04 inch.
" east " = .08 "

No perceptible scaling.

Description of Specimen.	Load. Lbs.	Load. Lbs. per sq. in.	Deviations. N.	S.	E.	W.	Remarks.
			In.	In.		In.	
Mark, K 20·	00	00	..	.02	..	.04	
	500	....	..	.02	..	.04	
Length, 60.00 in.	5 000	....	..	.02	..	.06	
	6 000	....	..	.02	..	.07	
Size,	7 000	....	..	.01	..	.07	
1.005 x .995 in.	8 000	....	..	00	..	.07	
	9 000	....	..	00	..	.07	
	10 000	....	..	00	..	.08	
	11 000	....	.01	..	..	.09	
	12 000	....	.02	..	..	.10	
	12 800	12 800	..	..	..	..	Went rather suddenly.
	6 400	6 400	.68	..	..	.11	
	500	....	00	..	..	.05	
	8 000	....	.06	..	..	.08	
	9 000	....	.08	..	..	.10	
	9 000	9 000	..	..	..	..	Went rather slowly.
	7 000	7 000	.52	..	..	.11	
	500	....	.01	..	..	.05	
	5 000	....	.03	..	..	.06	
	6 000	....	.03	..	..	.07	
	7 000	....	.04	..	..	.07	
	8 000	....	.06	..	..	.08	
	9 000	9 000	..	..	..	..	Failed.
	7 000	7 000	.56	..	..	..	
	6 800	....	..	..	..	.11	
	500	....	..	..	..	..	
	5 000	....	..	.07	..	.06	By pressure on rockers to cause bar to bend in opposite direction.
	6 000	....	.	.08	..	.06	
	7 000	....	..	.07	..	.07	
	8 000	....	..	.08	..	.07	
	9 000	....	..	.08	..	.07	
	10 000	....	..	.08	..	.08	
	11 000	....	..	.09	..	.08	
	12 000	....	..	.10	..	.09	
	13 000	....	..	.11	..	.10	
	14 000	....	..	.13	..	.11	
	14 900	14 900	..	..	..	..	Failed.
	6 700	6 700	..	.86	..	..	Rockers free.
	500	....	..	.05	..	.04	
	5 000	....	..	.06	..	.06	
	6 000	....	..	.06	..	.06	
	7 000	....	..	.06	..	.07	
	8 000	....	..	.07	..	.07	
	9 000	....	..	.07	..	.07	
	10 000	....	..	.07	..	.08	
	11 000	....	..	.08	..	.09	
	12 000	....	..	.09	..	.09	
	13 000	....	..	.10	..	.09	
	14 000	....	..	.11	..	.11	
	15 000	15 000	..	..	..	..	Failed.
	6 400	6 400	..	.86	..	..	
	500	...	..	.05	..	..	
	500	....	..	.03	..	..	By pressure.
	5 000	....	..	.03	..	.06	
	10 000	....	..	.03	..	.08	
	11 000	....	..	.04	..	.09	
	12 000	.. .	..	.04	..	.09	
	13 000	....	..	.04	..	.10	
	14 000	....	..	.04	..	.11	
	15 000	....	..	.04	..	.13	
	16 000	....	..	.04	..	.15	
	17 000	....	..	.04	..	.17	
	18 000	18 000	..	..	..	..	Started to fail along axis and changed.
	5 400	5 400	.89	..	..	..	
	500	....	.06	..	..	.07	Removed specimen.

After Specimen Removed.

Ordinate east at middle, = .06 inch.
" south " = .06 "

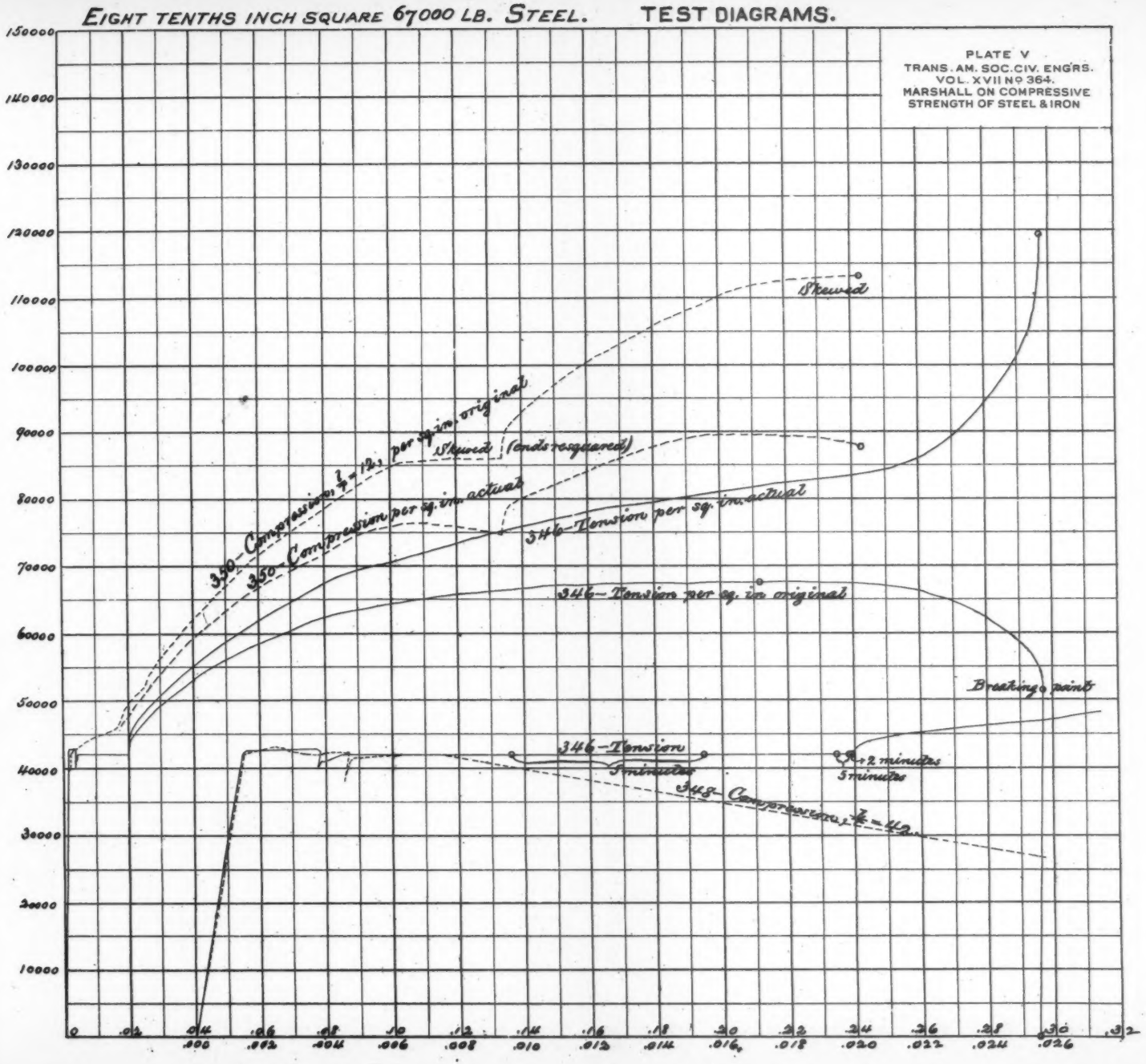
Description of Specimen.	Load. Lbs.	Load. Lbs. per sq. in.	Deviations. N.	S.	E.	W.	Remarks.
				In.			
Mark, K 17·	00	00	..	.05	..	.06	
	200	....	..	.05	..	..	
Length, 80.00 in.	500	....	..	.05	..	..	
	1 000	....	..	.05	..	..	
Size,	2 000	....	..	.07	..	..	
1.005 x .995 in.	3 000	....	..	.07	..	..	
	3 900	3 900	..	.41	..	..	Failed.
	3 600	3 600	..	.55	..	..	
	500	....	..	.09	..	..	
	2 000	....	..	.01	..	..	By pressure to bar.
	3 000	....	..	.02	..	..	
	4 000	....	..	.03	..	..	
	5 000	....	..	.04	..	..	
	6 000	6 000	..	..	..	..	Failed.
	3 100	3 100	..	.62	..	..	
	500	....	..	.07	..	..	Specimen removed.

Before Testing.

Ordinate north	12	24	36	40	44	56	68	inches.
	.03	.04	.05	.05	.05	.03	.01	inch.
" east..	12	24	36	40	44	56	68	80	inches.
	.02	.09	.07	.06	.05	.01	0	—.04	inch.

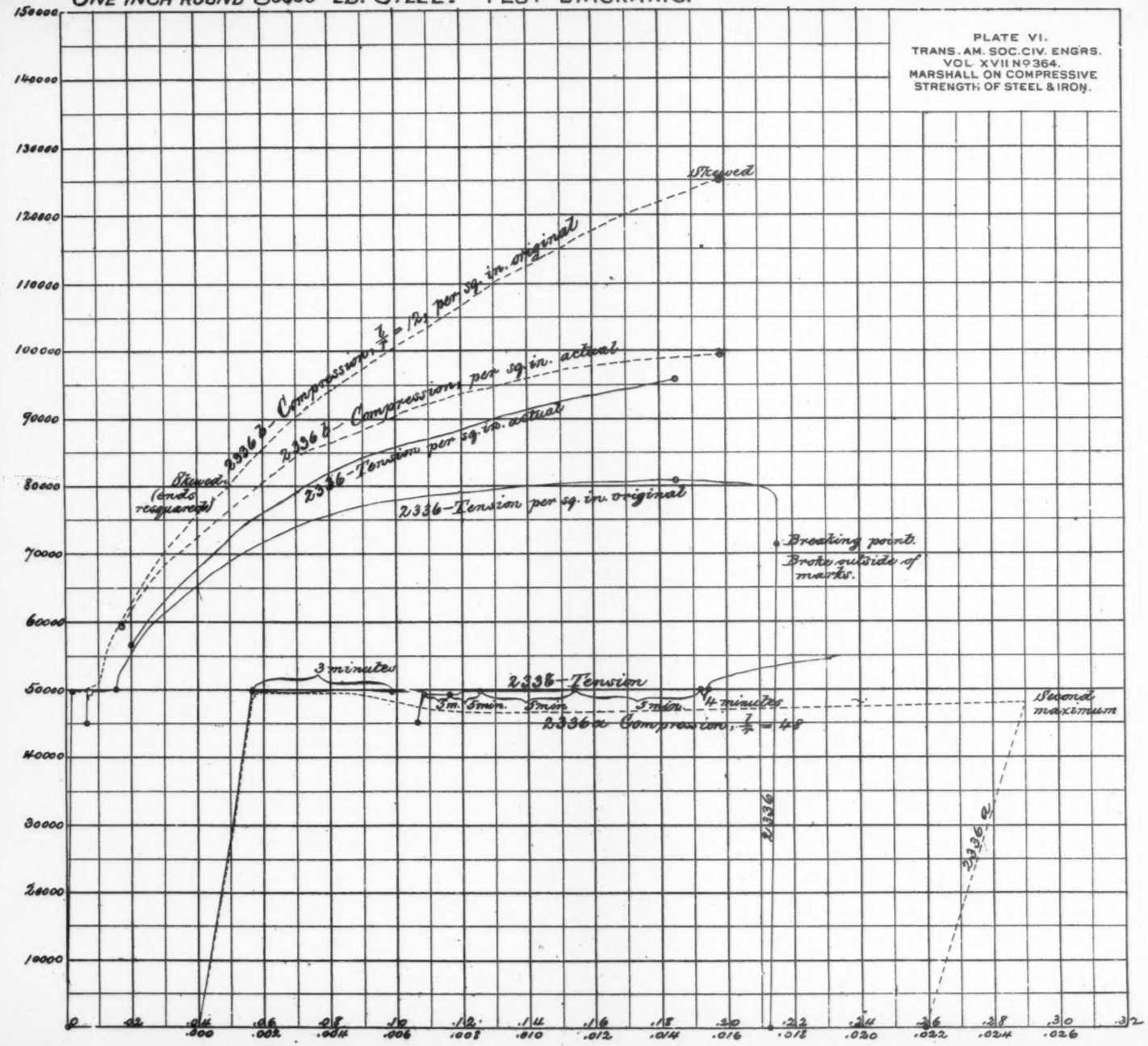
After Removal.

Ordinates north	12	24	36	40	44	56	68	inches.
	.04	.06	.07	.06	.05	.03	.01	inch.
" east..	12	24	36	40	44	56	68	80	inches.
	.03	.07	.07	.05	.04	.01	0	—.04	inch.


EIGHT TENTHS INCH SQUARE 67000 LB. STEEL. TEST DIAGRAMS.
PLATE V
TRANS. AM. SOC. CIV. ENG'RS.
VOL. XVII No 364.
MARSHALL ON COMPRESSIVE
STRENGTH OF STEEL & IRON
150000
140000
130000
120000
110000
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
Skewed
Skewed (ends reground)
350 – Compression per sq. in. original
350 – Compression per sq. in. actual
346 – Tension per sq. in. actual
346 – Tension per sq. in. original
Breaking point
346 – Tension
5 minutes
+2 minutes
5 minutes
346 – Compression, l/r = 42
0
.02
.04
.000
.06
.002
.08
.004
.10
.006
.12
.008
.14
.010
.16
.012
.18
.014
.20
.016
.22
.018
.24
.020
.26
.022
.28
.024
.30
.026
.32

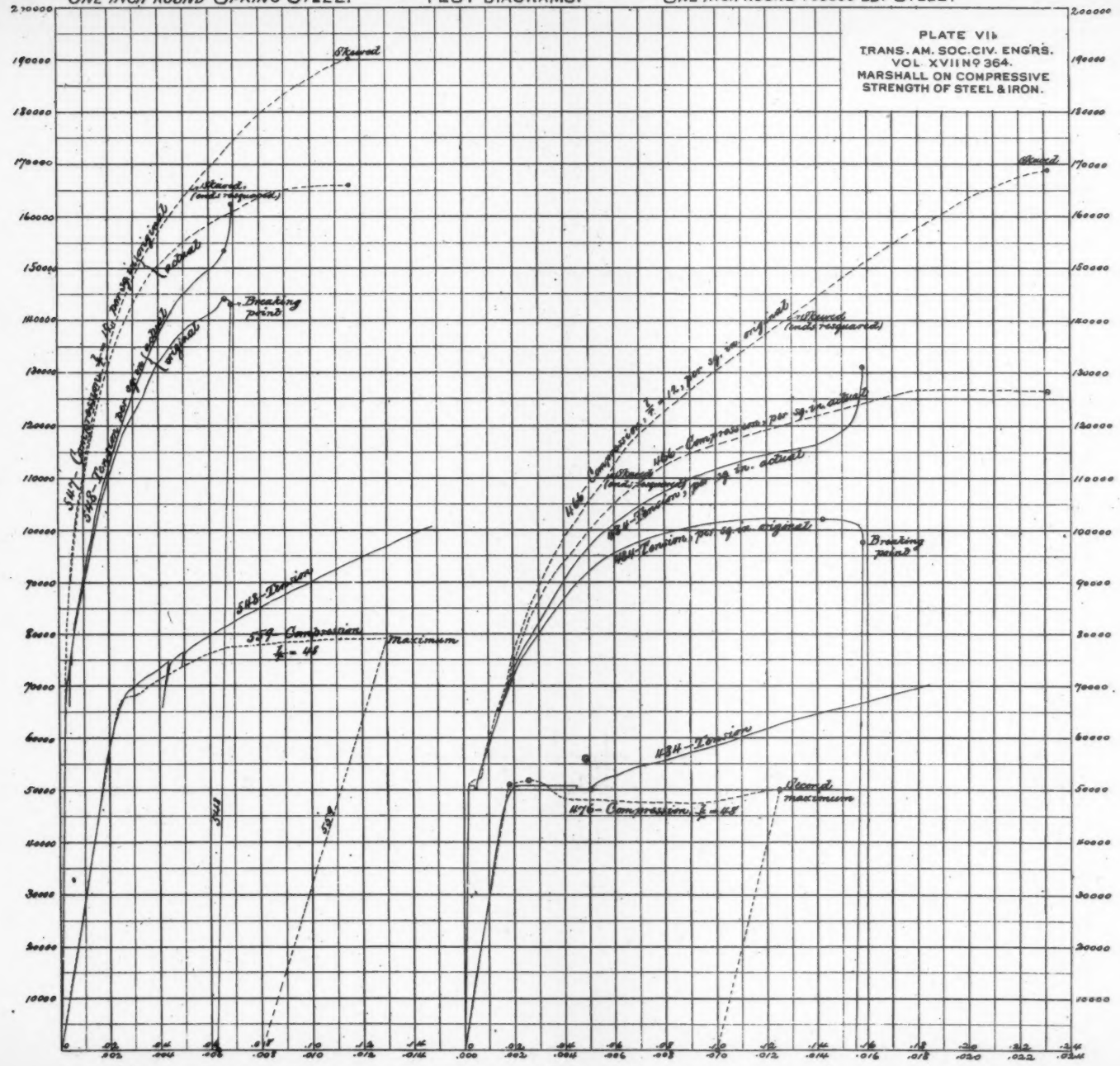
ONE INCH ROUND 80000 LB. STEEL. TEST DIAGRAMS.

PLATE VI.
TRANS. AM. SOC. CIV. ENGRS.
VOL. XVII No 364.
MARSHALL ON COMPRESSIVE
STRENGTH OF STEEL & IRON.

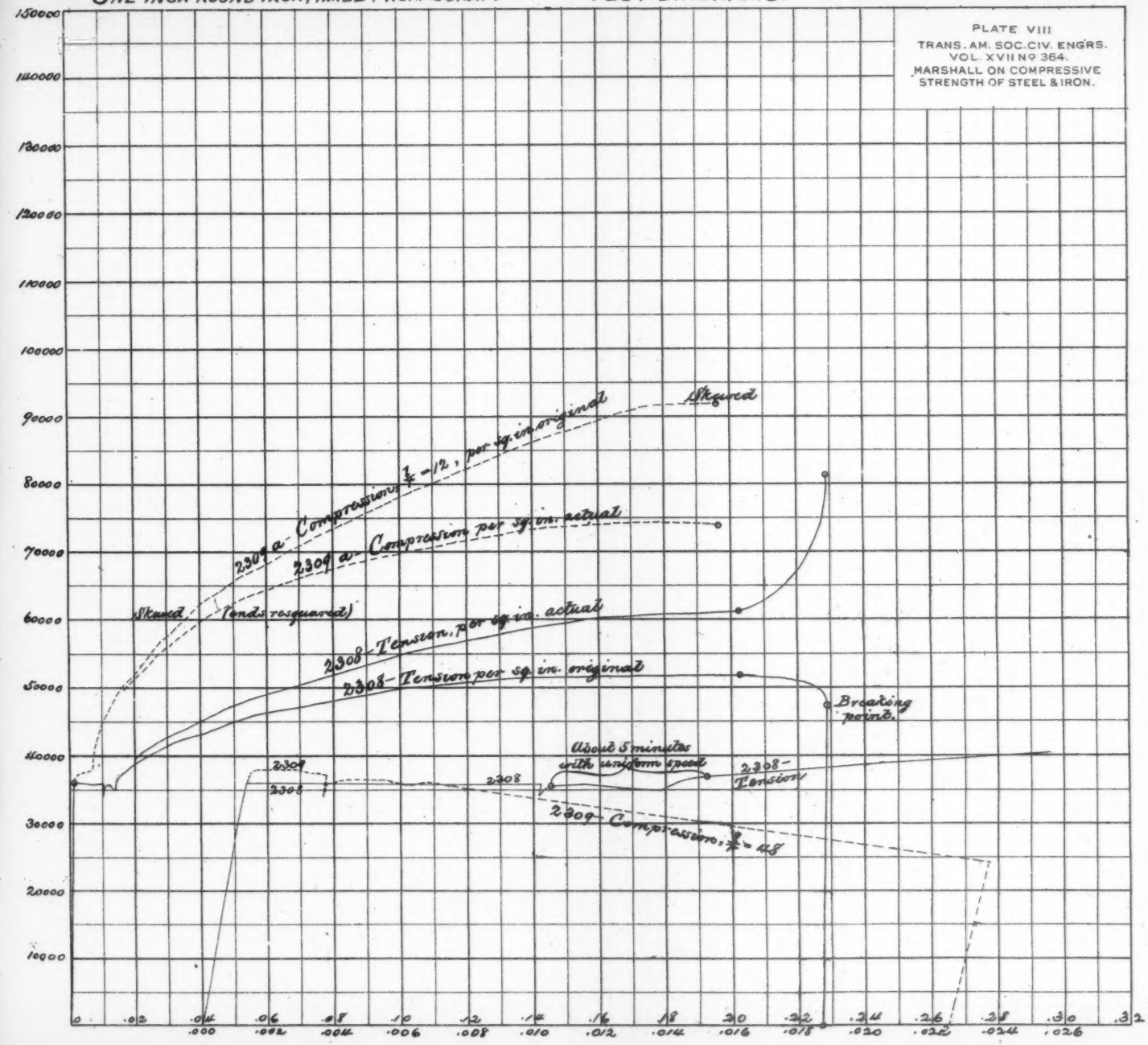


ONE INCH ROUND SPRING STEEL. TEST DIAGRAMS. ONE INCH ROUND 100000 LB. STEEL.

PLATE VII
TRANS. AM. SOC. CIV. ENG'RS.
VOL. XVIII N° 364.
MARSHALL ON COMPRESSIVE
STRENGTH OF STEEL & IRON.

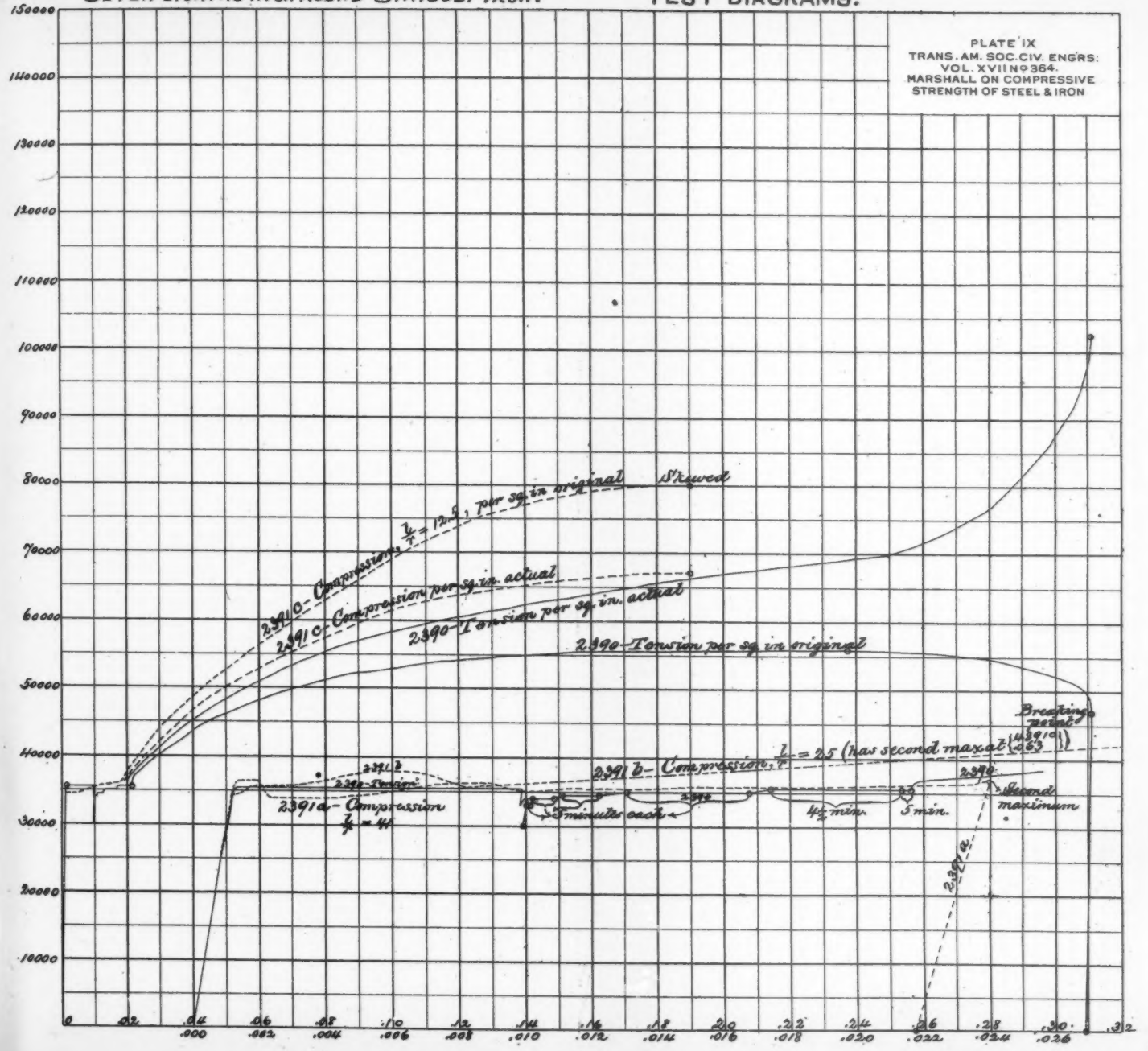


ONE INCH ROUND IRON, MADE FROM SCRAP. TEST DIAGRAMS.



SEVEN EIGHTHS INCH ROUND STAYBOLT IRON. TEST DIAGRAMS.

PLATE IX
TRANS. AM. SOC. CIV. ENG'RS.
VOL. XVII N° 364.
MARSHALL ON COMPRESSIVE
STRENGTH OF STEEL & IRON



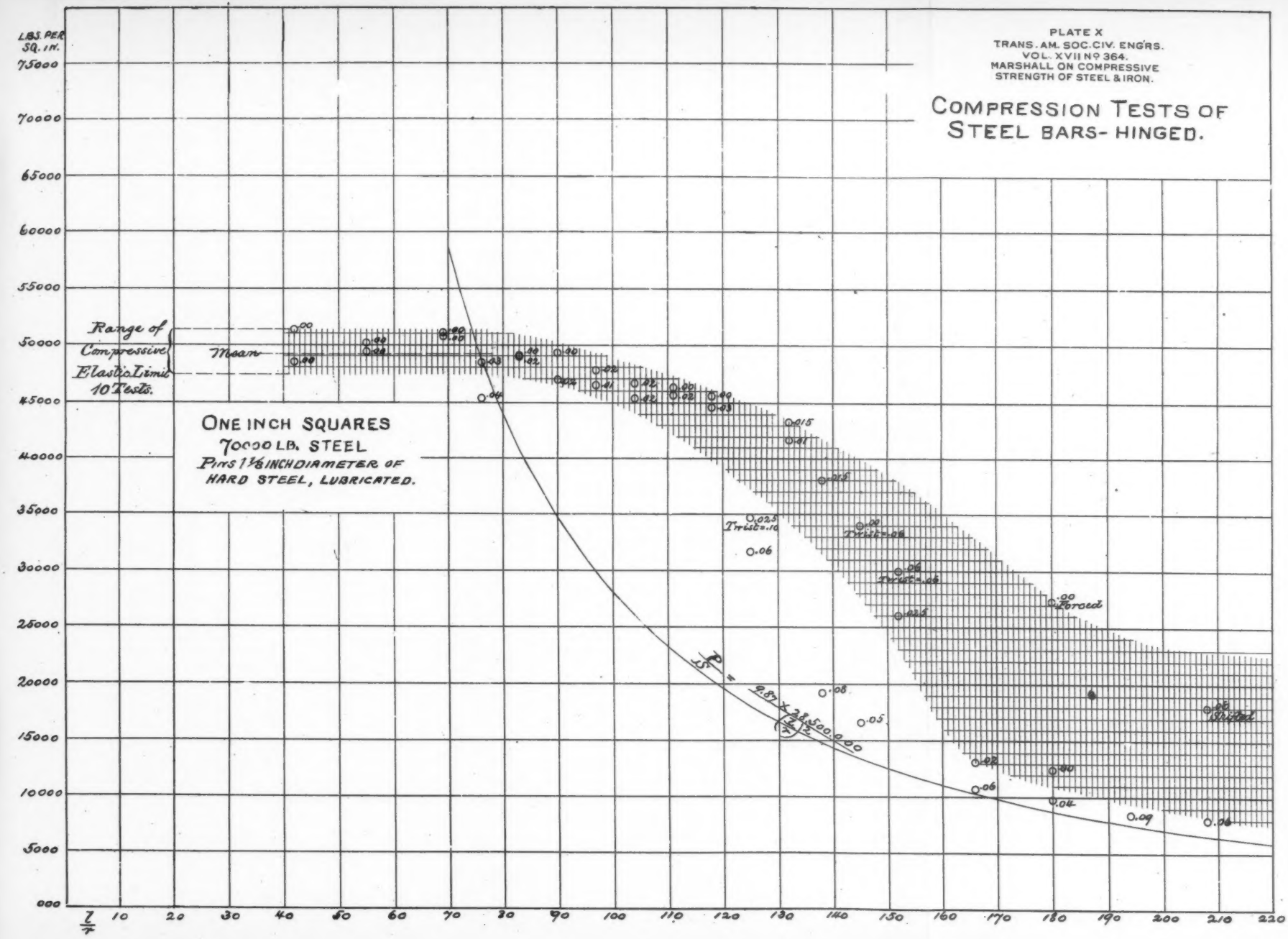


PLATE X
TRANS. AM. SOC. CIV. ENG'RS.
VOL. XVII Nº 364.
MARSHALL ON COMPRESSIVE
STRENGTH OF STEEL & IRON.
COMPRESSION TESTS OF
STEEL BARS- HINGED.
LBS. PER SQ. IN.
75000
70000
65000
60000
55000
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
000
Range of Compressive Elastic Limit 10 Tests.
Mean
ONE INCH SQUARES
70000 LB. STEEL
PINS 1 1/8 INCH DIAMETER OF
HARD STEEL, LUBRICATED.
Forced
Twist=.10
Twist=.08
Twist=.06
Twisted
l/r
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220

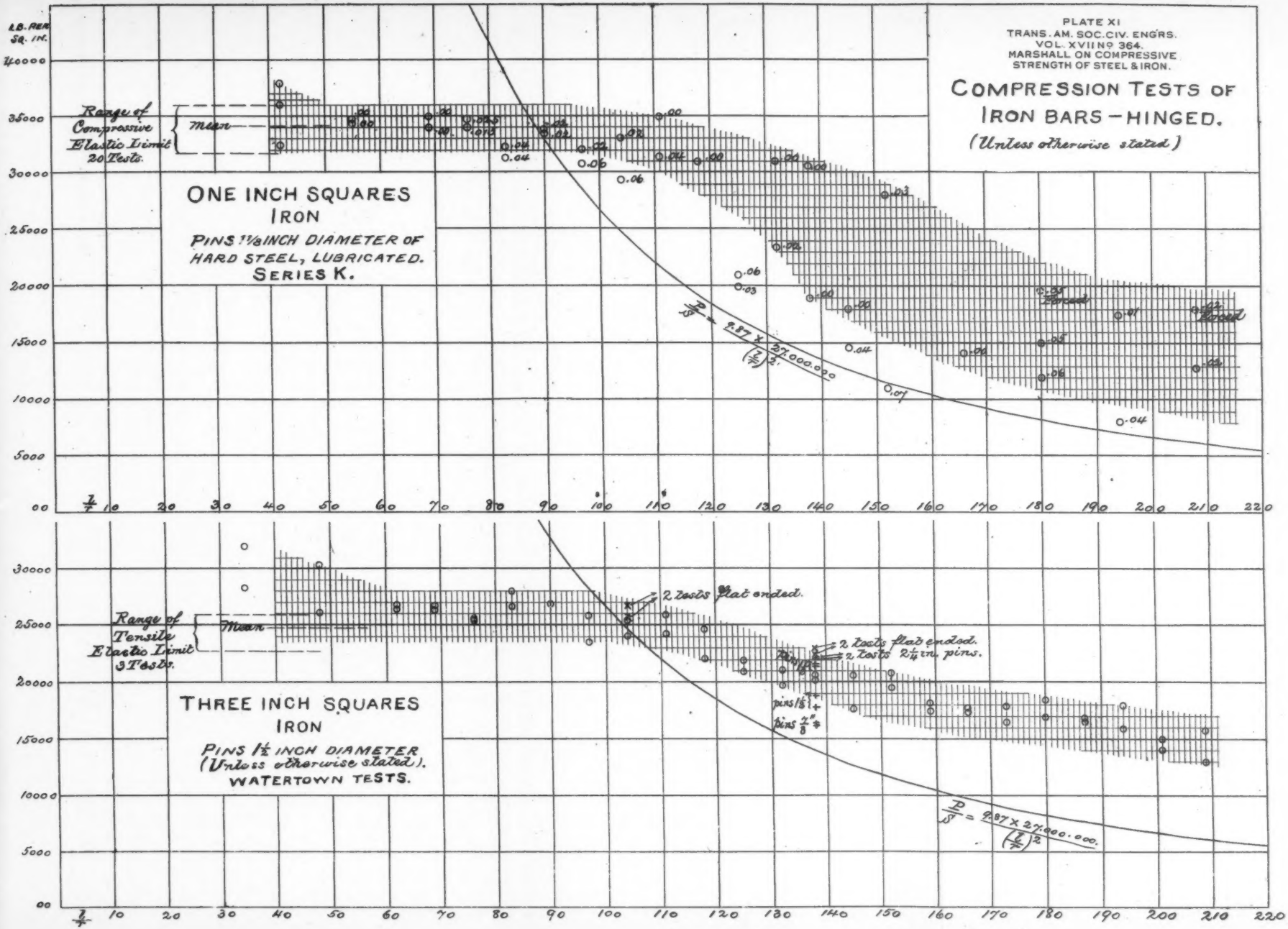
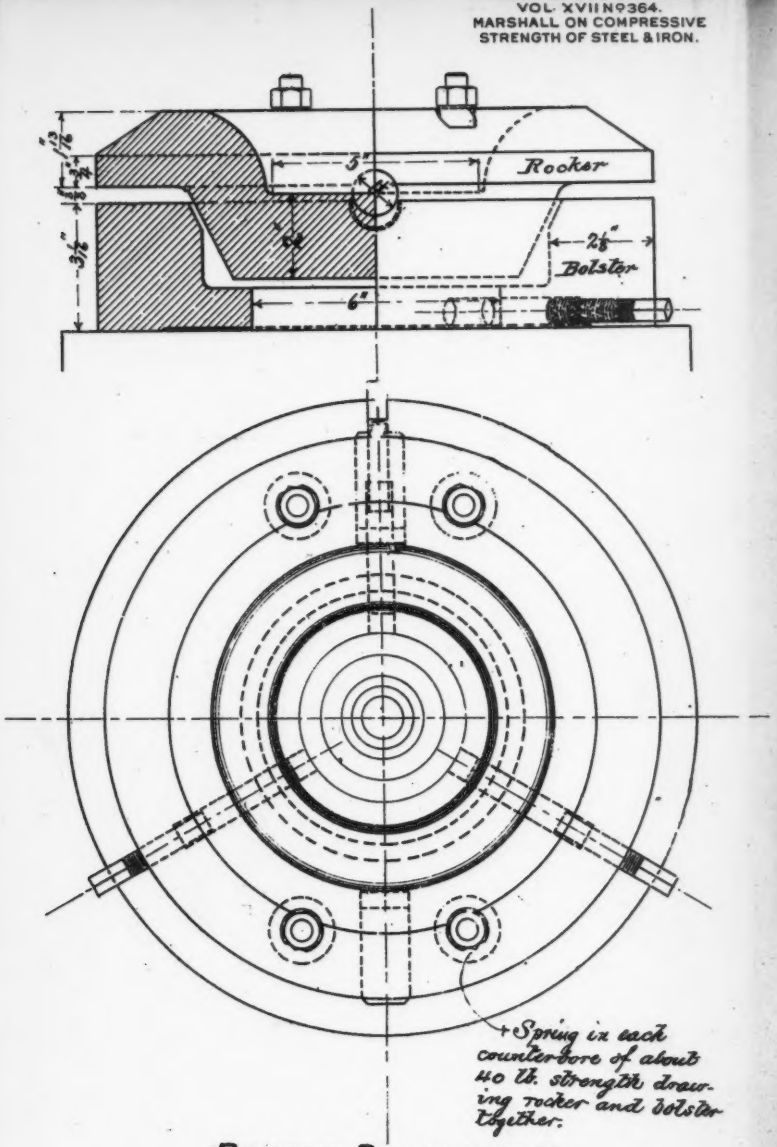


PLATE XI
TRANS. AM. SOC. CIV. ENGRS.
VOL. XVII Nº 364.
MARSHALL ON COMPRESSIVE STRENGTH OF STEEL & IRON.
COMPRESSION TESTS OF IRON BARS – HINGED.
(Unless otherwise stated.)
LB. PER SQ. IN.
Range of Compressive Elastic Limit 20 Tests.
mean
ONE INCH SQUARES IRON
PINS 1 1/8 INCH DIAMETER OF HARD STEEL, LUBRICATED.
SERIES K.
P/S = 9.87 × 27,000,000 / (l/r)²
Range of Tensile Elastic Limit 3 Tests.
Mean
THREE INCH SQUARES IRON
PINS 1½ INCH DIAMETER (Unless otherwise stated).
WATERTOWN TESTS.
2 tests flat ended.
2 tests flat ended.
2 tests 2¼ in. pins.
pins 1⅛
pins 2"
P/S = 9.87 × 27,000,000. / (l/r)²



ROCKER BEARINGS FOR
HINGED END COMPRESSION TESTS.